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PROCEEDINGS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY

HELD AT PHILADELPHIA

FOR PROMOTING USEFUL KNOWLEDGE

VOL. LII NOVEMBER–DECEMBER, 1913 No. 212

THE MARINE TERTIARY STRATIGRAPHY OF THE NORTH PACIFIC COAST OF AMERICA.

BY RALPH ARNOLD AND HAROLD HANNIBAL.

(PLATES XXXVII–XLVIII.)

COLUMNAR SECTION OF THE COLUMBIA RIVER AND SHOALWATER BAY DISTRICT.

Pleistocene marine terraces, 50′	
Pliocene basalt	
Monterey formation, 400′	
Astoria Series	*Seattle formation* tuffaceous shales and sandstone with interbedded basalts of Nazel, Grays River, Ilwaco, and Astoria. 5,000′
	San Lorenzo formation tuffaceous sandstones and shales with interbedded basalts of Winlock, Pe Ell, Holcomb, Clatskanie, and Scapoose. 10,000′
Tejon Series	*Olequa formation* tuffaceous lignitic sandstones of Little Falls and Coal Creek above Stella. 3,000′
	Chehalis formation tuffaceous lignitic sandstones and shales of marine and estuarine origin east of Winlock and in the upper Cowlitz Basin. 10,000′
Bedrock complex	

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Columnar Section of Willamette Valley and Upper Umpqua Basin.

Pliocene basalt	
Astoria Series	*San Lorenzo* tuffs of Silverton and Eugene. 1,000′
Tejon Series	*Arago formation* tuffaceous and arkose sandstone of Umpqua Basin, coarse basic tuffs farther north on Santiam River. 10,000′
Bedrock complex	

Columnar Section of the Coast Range and Coast of Oregon.

Marine Pleistocene terraces, 50′	
Elk River formation, 300′	
Merced formation, 50′	
Empire formation, 500′	
Monterey formation sandstone and clay shale of Newport. 2,000′	
Astoria Series	*Seattle formation* tuffaceous sandstone and shale of Nehalem and Yaquina Bays. 5,000′
	San Lorenzo formation tuffaceous sandstone and shale of Upper Nehalem and Yaquina Rivers. 5,000′
Tejon Series	*Arago formation* tuffaceous lignitic sandstones and shales of Coos Bay district becoming more and more tuffaceous to north and grading into coarse tuffs and basaltic flows of Wilson River and South Nehalem River. 10,000′
Bedrock complex	

Columnar Section of the Grays Harbor and Chehalis Valley District.

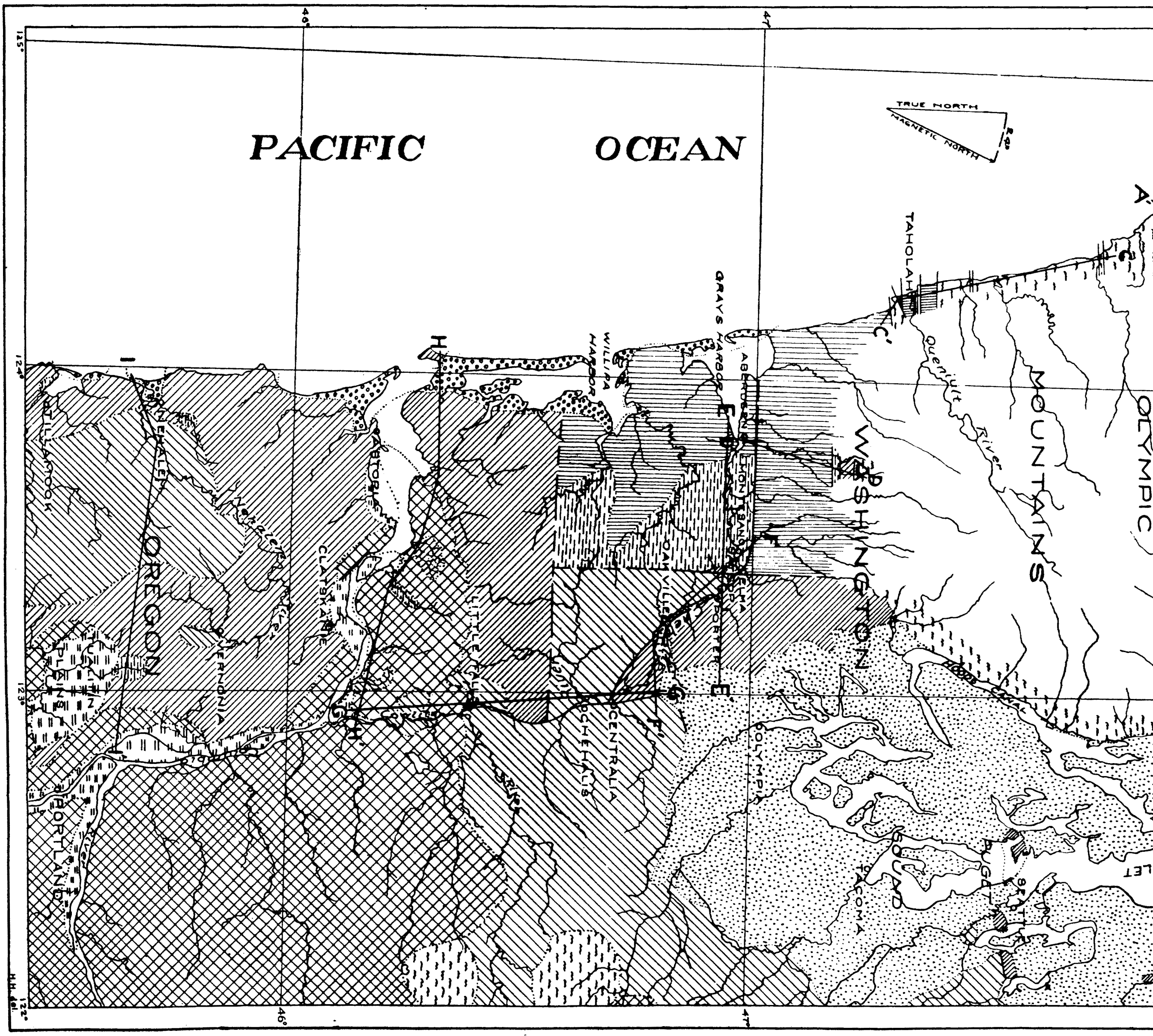
	Admiralty till
	Empire formation sandstones and tuffaceous shales with basalt tuffs at base, west and north of Chehalis Valley. 4,000′
	Monterey formation sandstones and clay shales south of Chehalis Valley. 4,000′
Astoria Series	*Seattle formation* tuffaceous s.s. and sh. of Delazine Cr. 1,600′
	San Lorenzo formation tuffaceous sandstone and shale at Lincoln Creek and north of Oakville, Porter, and Elma with basalts at base. 3,000′
Tejon Series	*Chehalis formation* tuffaceous lignitic sandstones and shales, marine and estuarine with interbedded basic flows and tuffs at Chehalis and the Balch syncline. 9,000′
	Bedrock complex

Columnar Section of Puget Sound and the San Juan Islands.

	Saanich formation, 50′
	Vashon drift
	Admiralty till
Astoria Series	*Seattle formation* conglomerates and tuffaceous sandstones and shales of the Seattle monocline. 4,000′
	San Lorenzo formation tuffaceous sandstones and shales with basalts and andesites at base, of Bean Point and Port Townsend. 5,000′
Tejon Series	*Olequa formation* tuffaceous lignitic sandstones and shales of marine and estuarine origin forming the coal series of Whatcom County and the upper 12,000′ of the Pierce County section.
	Chehalis formation tuffaceous lignitic sandstones and shales of marine and estuarine origin of Fairfax and the Pierce County coal field. 5,000′
	Bedrock complex

COLUMNAR SECTION OF THE STRAITS OF FUCA AND WEST COAST OF THE OLYMPIC PENINSULA.

	Admiralty till
	Merced formation, 400′
	Empire formation sandstones of Bogochiel River, tuffaceous shale of Taholah. 1,600′
	Monterey formation lignitic sandstone of Clallam Bay section. 2,000′
Astoria Series	*Twin River formation* clay shales of Twin River section. 2,000′
	Seattle formation tuffaceous shale and sandstone of Sekin River and Gettysburg. 3,000′
	San Lorenzo formation tuffaceous shale and sandstone of southwest coast of Vancouver Island, heavy conglomerates of the Cape Flattery section. 17,000′
	Sooke formation sandstones and conglomerates of Muir Creek. 1,600′
Tejon Series	*Arago formation* basalt tuffs of Port Crescent and west of Discovery Harbor. 3,000′
	Bedrock complex



Geologic Map of the Tertiary Deposits of the North Pacific Coast of the United States and Southern Vancouver Island. Fo

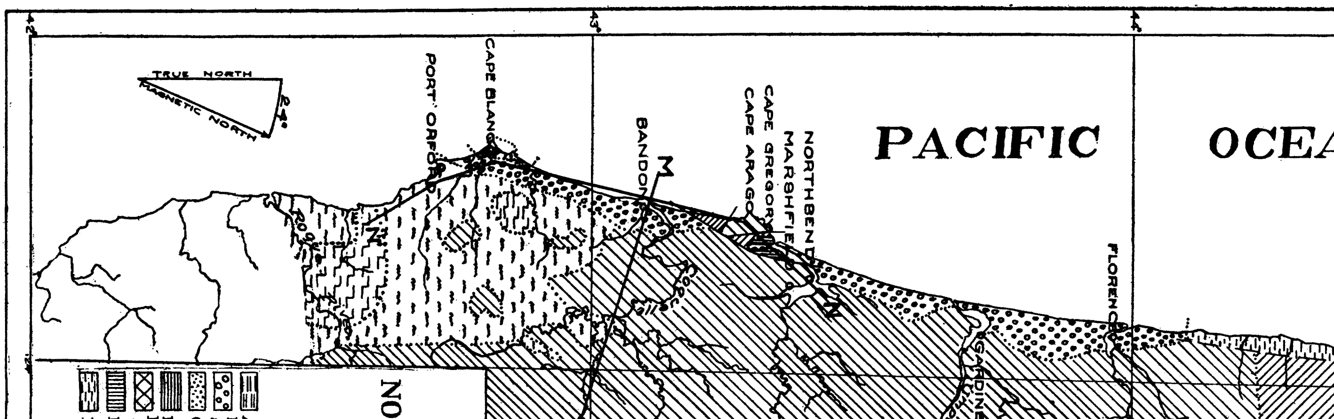
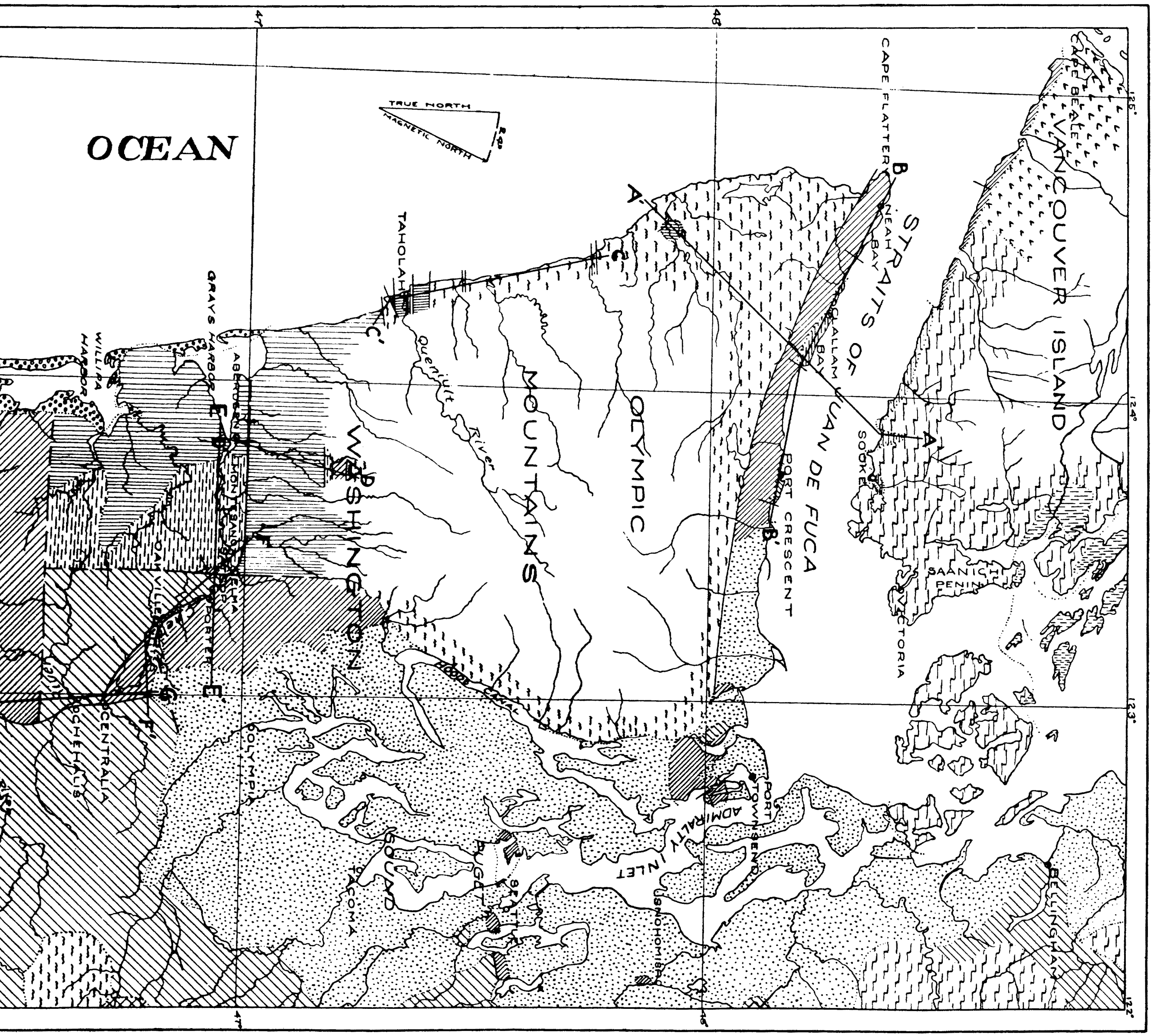
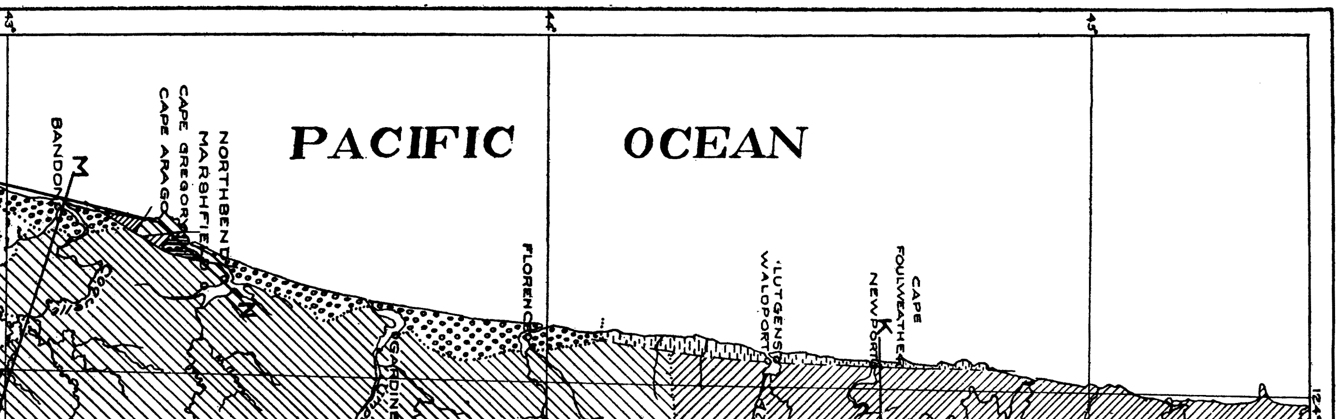


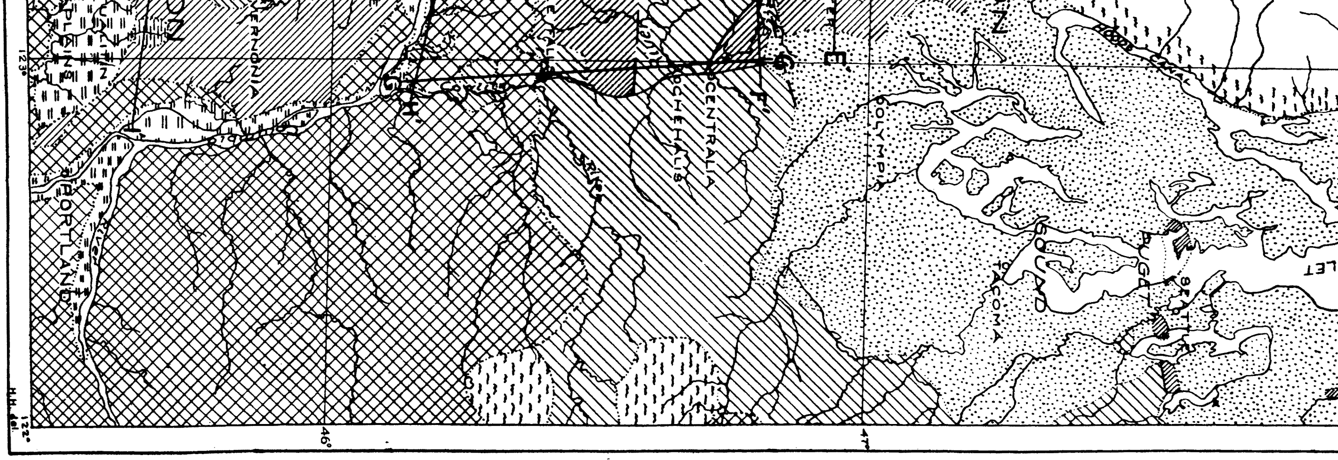
PLATE XXXVII



e North Pacific Coast of the United States and Southern Vancouver Island. For explanatory symbols see Plate XXXVIII.

PLATE XXXVIII





Geologic Map of the Tertiary Deposits of the North Pacific Coast of the United States and Southern Vancouver Island. Fo

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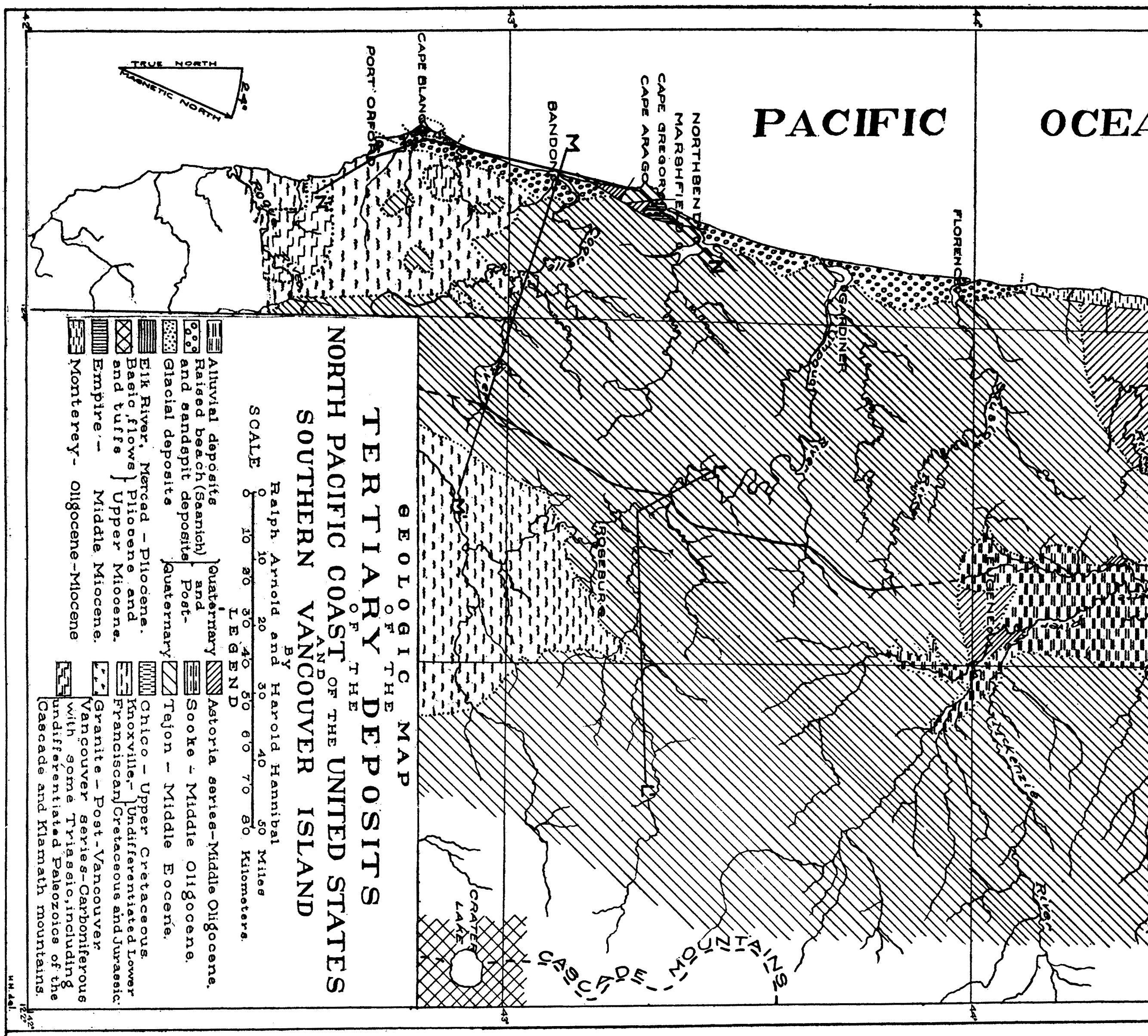
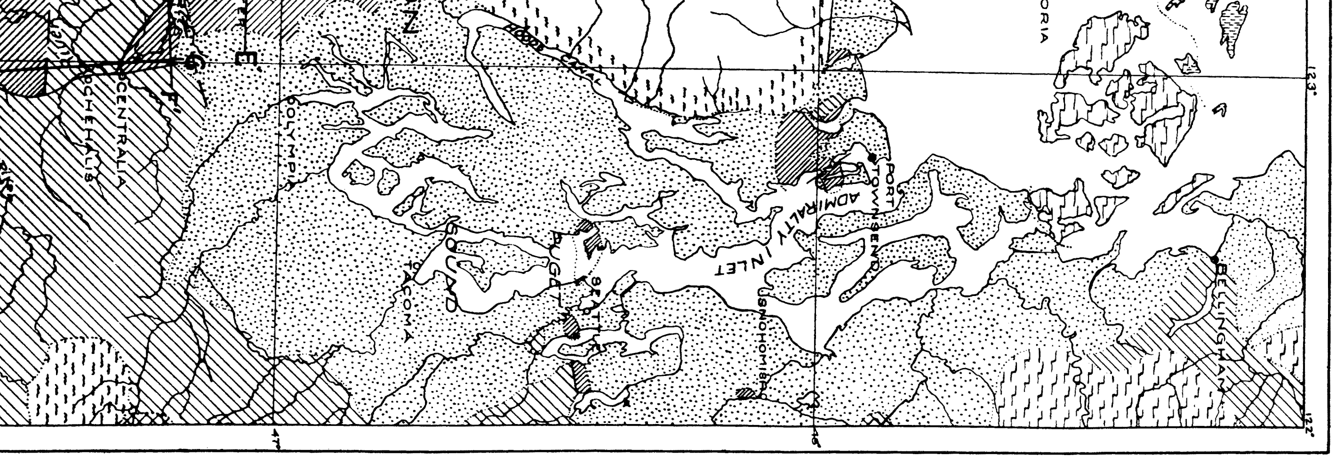
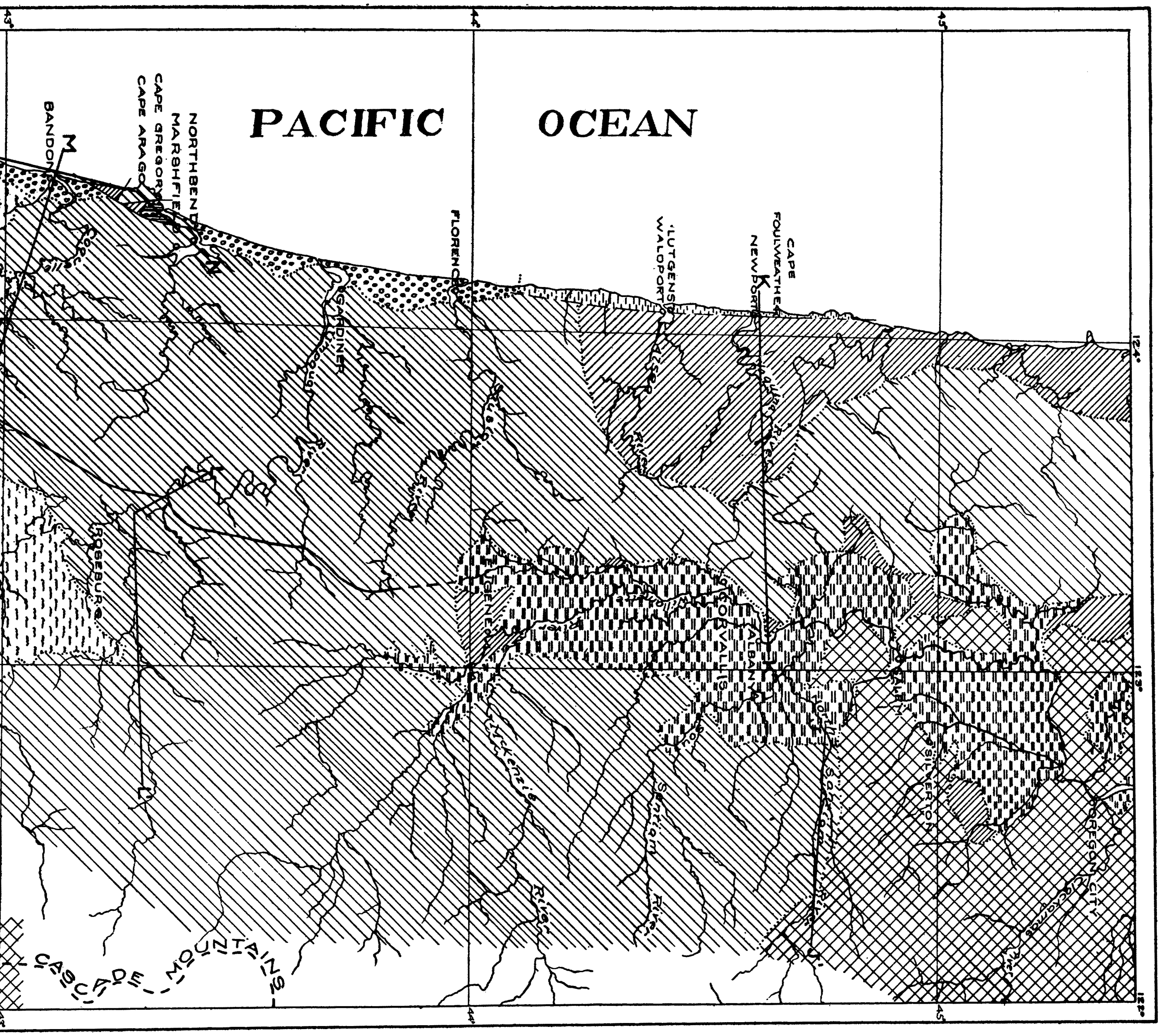
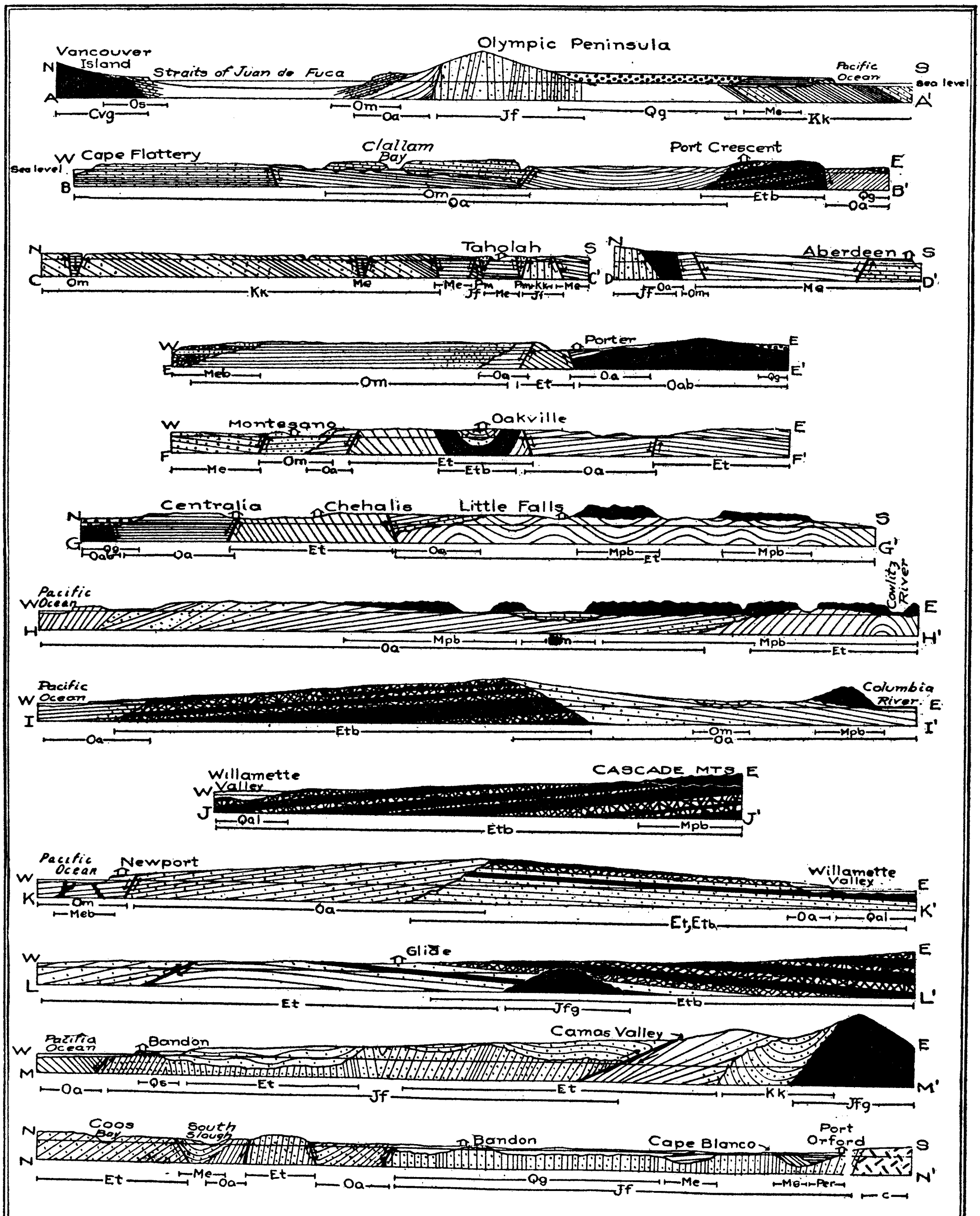

GEOLOGIC MAP OF THE TERTIARY DEPOSITS OF THE NORTH PACIFIC COAST OF THE UNITED STATES AND SOUTHERN VANCOUVER ISLAND
BY Ralph Arnold and Harold Hannibal
SCALE 0 10 20 30 40 50 Miles
0 10 20 30 40 50 60 70 80 Kilometers
LEGEND
Alluvial deposits
Raised beach (Saanich) and sandspit deposits
Glacial deposits
Quaternary and Post-Quaternary
Elk River, Merced - Pliocene.
Basic flows and tuffs
Pliocene and Upper Miocene.
Empire - Middle Miocene.
Monterey- Oligocene-Miocene
Astoria series-Middle Oligocene.
Sooke - Middle Oligocene.
Tejon - Middle Eocene.
Chico - Upper Cretaceous.
Knoxville- Franciscan
Undifferentiated Lower Cretaceous and Jurassic.
Granite - Post-Vancouver
Vancouver series-Carboniferous with some Triassic, including undifferentiated Paleozoics of the Cascade and Klamath mountains.
TRUE NORTH
MAGNETIC NORTH
24°
PACIFIC
OCEA
CAPE BLANCO
PORT ORFORD
BANDON
CAPE ARAGO
CAPE GREGORY
MARSHFIELD
NORTHBEND
FLORENCE
GARDINER
ROSEBURG
EUGENE
Mackenzie
River
CRATER LAKE
CASCADE MOUNTAINS
42°
43°
44°
124°
122°
H.H. del.



e North Pacific Coast of the United States and Southern Vancouver Island. For explanatory symbols see Plate XXXVIII.

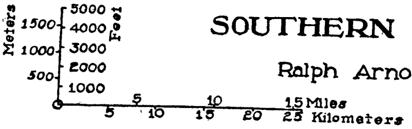




GEOLOGIC SECTIONS OF THE TERTIARY DEPOSITS OF THE NORTH PACIFIC COAST OF THE UNITED STATES AND SOUTHERN VANCOUVER ISLAND

BY

Ralph Arnold and Harold Hannibal



LEGEND

Qal	Alluvial deposits
Qs	Raised beach deposits
Qg	Glacial deposits
Per	Elk River
Pm	Merced
Mpb	Upper Miocene and Pliocene basalts
Me	Empire
Mb	Empire basalts
Om	Monterey
Oa	Astoria
Oab	Astoria basalts
Os	Sooke
Et	Tejon
Etb	Tejon basalts
Kk	Knoxville
Jfg	Franciscan greenstones and serpentine
Jf	Franciscan
Cvg	Vancouver greenstones
C	Colebrook schist

H.H. del.

General Remarks.

The recognition of marine tertiary on the North Pacific Coast of America dates back to 1848 when Conrad[1] described several fossil mollusca from "the tertiary deposits on the Columbia River near Astoria." More recent studies by Richardson, Condon, Diller, Willis and Smith, the senior author, and other writers too numerous to mention have shown that such rocks underlie all of Oregon west of the Cascade Range and north of the Klamath-Siskiyou Mountains, western Washington except the Olympic Range, and portions of Vancouver Island. The several geological horizons have in most instances been named and something is known of their fossil contents but their stratigraphic relations one to another and their correlatives among the closely related formations of California are scarcely understood.

Several years ago the senior writer visited the more important fossil localities then known in western Oregon and Washington in the interests of the United States Geological Survey. No general report of the work was published owing to the necessity of further field studies but descriptions of the stratigraphy of particular districts are to be found in "Gold Placers of the northwestern coast of Washington,"[2] "Coal in Clallam County, Washington"[3] and "A Geological Reconnaissance of the Olympic Peninsula."[4] Some of the palæontological material obtained was described in "The Tertiary and Quaternary Pectens of California,"[5] "Descriptions of New Cretaceous and Tertiary Fossils from the Santa Cruz Mountains, California"[6] and "The Miocene of Astoria and Coos Bay, Oregon."[7] The distribution of land and water in this region during the different tertiary periods is treated of in a preliminary way in "Environment of the Tertiary Faunas of the Pacific Coast of the United States."[8]

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[1] *Amer. Jl. Sci.*, 2d series, V., 1848, p. 432.

[2] Arnold, R., Bull. 260, U. S. Geol. Sur., 1905, p. 154–7, Fig. 11.

[3] Ibid., p. 413–421.

[4] Arnold, R., *Bull. Geol. Soc. Am.*, XVII., 1906, p. 451–468, Pl. 55–58.

[5] Arnold, R., Prof. Pap. 47, U. S. Geol. Sur., 1906, 264 pp., 53 Pl.

[6] Arnold, R., Proc. U. S. Nat. Mus., XXXIV., 1908, p. 345–390, Pl. XXXI.–XXXVII.

[7] Dall, W. H., Prof. Pap. 59, U. S. Geol. Sur., 1909, 284 pp., 23 Pl.

[8] Arnold, R., *Jour. of Geol.*, XVII., 1909, p. 509–533.

In 1911 the junior writer was commissioned to continue the exploration at private expense and the months of June, July, and August were spent in examining the various described sections and districts of the Oregon coast and western Washington. With the opening of the spring of 1912 as opportunity offered, short trips were undertaken from Seattle to points about Puget Sound and the Straits of Fuca, and three weeks were spent on the southwest coast of Vancouver Isand. In June extended field work was resumed and a trip made from Port Townsend west to Cape Flattery along the north coast of Washington, following which two months were spent in southwestern Washington. Six weeks more were given over to further collecting in western Oregon, field work being concluded in October.

The present paper, preliminary to more extended accounts of the stratigraphy and palaeontology, is based primarily on the work done in 1911 and 1912. The faunas listed here include described species obtained at, or in the vicinity of, the several type sections or, if the deposits are referred to formations described first from California, characteristic faunas from some district on the North Pacific Coast in lieu.

Bedrock Complex.

The bedrock complex on which the marine tertiary deposits were laid down varies widely from place to place.

In southern Oregon the underlying rocks are chiefly Mesozoic, the Franciscan (Myrtle in part), Dothan, and Galice formations of Jurassic age, and the Knoxville (Myrtle in part), Horsetown, and perhaps also Chico formations which are Cretaceous (the Knoxville may extend into Jurassic). These have been partially described by Diller[9] and Londerback[10] though much work still needs to be done to elucidate the complicated stratigraphy.

In the Olympic Mountains the Tertiary rests indiscriminately

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[9] Roseburg Folio, No. 49, U. S. Geol. Sur., 1898; Port Orford Folio, No. 89, U. S. Geol. Sur., 1903; Mesozoic Sediments of Southwestern Oregon, *Am. Jour. Sci.*, XXIII., 1907, p. 401–421; "Strata containing the Jurassic Flora of Oregon," *Bull. Geol. Soc. Am.*, XIX., 1908, p. 367–402.

[10] "The Mesozoic of Southwestern Oregon," *Jour. of Geol.*, XIII., 1905, p. 514–555.

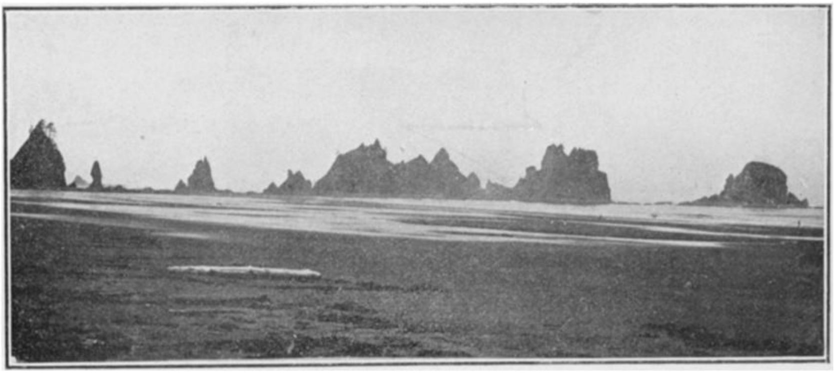

FIG. A.

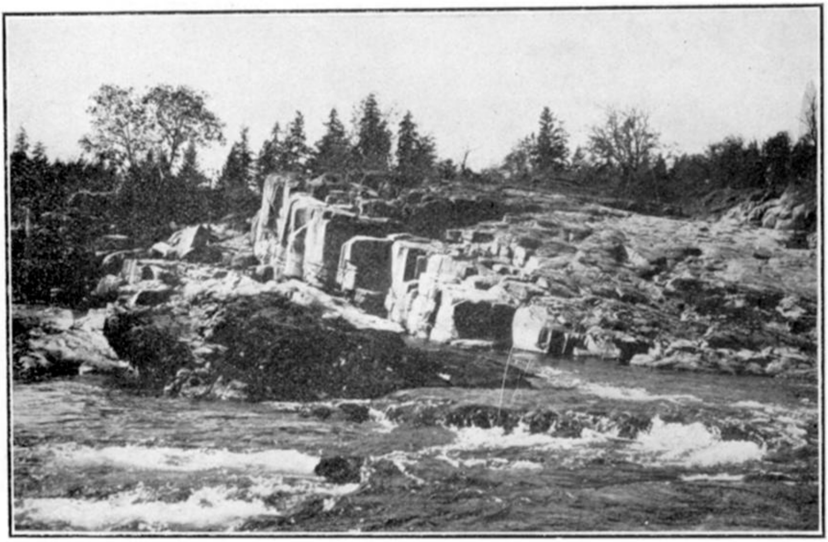

FIG. B.

FIG. A. Point of the Arches from Shi Shi Beach near Neah Bay, Washington. A characteristic exposure of Franciscan rocks such as form the Olympic complex.

FIG. B. Diabase flow intercalated in Arago beds (Tejon series) on Umpqua River near Glide, Oregon.

upon indurated shales, sandstones, and conglomerates of supposed Cretaceous age[11] and a great complex of metamorphic sandstone, shale, radiolarian chert, glaucophane schist, and greenstones cut by peridotite serpentine, a series closely resembling the Franciscan of southern Oregon and the California Coast Ranges.

In the Cascade Mountains of Oregon and southern Washington the contacts between the tertiary and older rocks are usually obscured by outpourings of lava but farther north Russell[12] has described Mesozoic and older sediments associated with granite, greenstones and serpentine.

On Vancouver Island the Vancouver Series underlies the Oligocene; it is composed of slates, limestones, and greenstone-diorites of supposed Carboniferous and perhaps also Triassic age, cut by biotite granite. This has been described by George M. Dawson.[13] Farther north in the Straits of Georgia Chico rocks have a wide distribution.

EOCENE DEPOSITS—THE TEJON SERIES.

Eocene deposits form a large proportion and from an economic standpoint the most important part of the Tertiary sediments of western Oregon and Washington. These belong so far as known exclusively to the Tejon Series. Everywhere that a contact has been observed the Tejon lies directly on the pre-tertiary rocks, so it appears that the Martinez formation (early Eocene) of California is not represented on the north Pacific coast. In addition to being the most widespread formation the Tejon is the most extensively developed. Prevailing low dips render it impossible to study it conveniently in any one section, but from data obtained in the coal field of Pierce County, Washington, and several other partial sections it is probable that 15,000 feet is not too great an estimate of the thickness of the series in western Washington, while in Oregon at least 13,000 feet of beds stratigraphically higher are present. This extraordinary development of sediments is only to be explained by a consideration of the nature of the deposits. These are at some points coarse basalt tuffs and at others, and by all odds this is the most prevalent type of sedimentation, worked over volcanic ejectmenta in the form of sandstones or shales deposited under estuarine conditions, evidently with considerable rapidity.

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[11] Arnold, R., *Bull. Geol. Soc. Am.*, XVIII., 1906, p. 459.

[12] "A Preliminary Paper on the Geology of the Cascade Mountains in Northern Washington," 20th Ann. Rept. U. S. Geol. Sur. (II), 1900, p. 83–210.

[13] 2d Ann. Rept. Geol. Sur. Can., 1887, p. 10*B*–13*B*.

Three divisions, the Chehalis, Olequa, and Arago formations, represent well-marked palæontological horizons that can be recognized by characteristic faunas and floras over the North Pacific Coast. The latter is not found in juxtaposition with the Chehalis and Olequa and may represent a later phase of the Eocene equivalent to the Ione of California.

Faunal Divisions of the Tejon Series.

Tejon Series	Arago formation	—zone of *Venericardia horni* variety with obsolete ribs	Tropical flora—fan-palms, magnolias, figs, and ferns.
	Olequa formation Chehalis formation	zone of *Venericardia horni* Gabb[14]	Austral flora—birches, sycamores and chestnuts.

The Chehalis and Olequa formations usually consist of fine material and are essentially estuarine deposits throughout, containing numerous lignite beds interstratified with alternating fresh water and marine sediments. The Arago of the Coos Bay-Port Orford coal fields is similar but commonly consists of coarser material partly arkose in character. Farther north in Oregon this horizon is represented by basic flows and coarse bedded tuffs occasionally carrying marine fossils. In the Roseburg district it is essentially tuffaceous sandstone of marine origin. Coarse basalt tuffs carrying marine fossils and interbedded with basic flows and a subordinate amount of sandstone on the north coast of Washington are also referred to this horizon on the basis of palaeontological evidence.

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[14] Usually cited as *V. planicosta* Lam., but the real *planicosta* is confined to the Martinez formation on the Pacific Coast.

Table of Correlation of the Tertiary and Quaternary Horizons of the Pacific Coast.

Age.	North Pacific Coast.		California.	
	Formation.	Chief Zone Fossils.	Formation.	Chief Zone Fossils.
Pleistocene			Upper San Pedro	
	Saanich		Lower San Pedro	
	Vashon Drift			
	Admiralty Till			
Pliocene	Elk River	*Cardium corbis* Mart. *Scutella oregonensis* Clark *Turris smithi* Arn.	Deadman Island (Santa Barbara Pliocene)	*Echinarachnius excentricus* Esch. *Turris smithi* Arn. *Turritella jewetti* Cpr.
	Merced	*Pecten dilleri* Dall *Scutella oregonensis* Clark	Merced, Purisima (in part), and Etchegoin	*Pecten healeyi* Arn. *Echinarachnius Gibbsi* Rem. *Scutella oregonensis* Clark *Scutella interlineata* Stimp
Miocene			Santa Margarita	*Astrodapsis antiselli* Conr. *Astrodapsis whitneyi* Gabb *Tamiosoma gregaria* Conr.
			Scutella gabbi–S. breweriana beds	*Astrodapsis antiselli* Conr. *Scutella gabbi* Rem. *Scutella breweriana* Gabb
	Empire	*Scutella gabbi* Rem. *Argobuccinum cammani* Dall *Mytilus middendorffi* Grnk. *Cardium coosense* Dall *Pecten coosensis* Shum. *Bullia bogackielii* Rgn.		
	Monterey (Clallam)	*Pecten propatulus* Conr. *Arca devincta* Conr. *Polinices saxea* Conr. *Venus clallamensis* Rgn. *Turritella oregonensis* Conr.	Monterey (Temblor)	*Pecten propatulus* Conr. *Arca devincta* Conr. *Ficus kernianus* Cooper *Agasoma barkerianum* Cooper *Polinices saxea* Conr.
Oligocene	Astoria: Twin River	*Acila gettysburgensis* Rgn. *Polinices olympidii* Rgn. *Turritella oregonensis* Conr.	Vaqueros	*Pecten magnolia* Conr. *Turritella inezana* Conr.
	Astoria: Seattle	*Acila gettysburgensis* Rgn. *Turcicula washingtoniana* Dall *Macrocallista vespertina* Conr.		
	Astoria: San Lorenzo	*Acila shumardi* Dall *Turcicula columbiana* Dall *Pecten branneri* Arn.	San Lorenzo	*Acila shumardi* Dall *Acila dalli* Arn. *Pecten branneri* Arn.
	Sooke	*Pecten branneri* Arn. *Macrocallista newcombei* Mrm. *Patella geometrica* Mrm.		
Eocene	Arago	*Venericardia horni* Gabb (obsolete ribbed variety)	Ione	*Venericardia horni* Gabb (obsolete ribbed variety)
	Tejon: Olequa	*Venericardia horni* Gabb *Pecten landesi* Arn.	Tejon	*Venericardia horni* Gabb
	Tejon: Chehalis	*Venericardia horni* Gabb *Meretrix californica* Gabb		
			Martinez	*Venericardia planicosta* Lam *Pholadomya nasuta* Gabb

The Chehalis Formation.

The term Chehalis sandstone was used by Lawson[15] for some arenaceous bedded tuffs containing marine Eocene fossils exposed in a water tunnel through the hill east of the city of Chehalis, Washington. The beds here form an intregal part of the south limb of an anticline in which several thousand feet of conformable strata are involved, the friable nature of the rock rendering an exact estimate of the thickness difficult without instrumental measurements. The upper beds exposed by this anticline are distinctly marine while the lowest are probably of freshwater origin judging by the presence of workable coal seams.

This anticline is in turn one of a series of folds whose axes have a general east-west trend, exposed along the lower slopes of the Cascade Range east of the Portland-Tacoma railway from a few miles south of the Cowlitz River northward to Tenino. Upwards of 10,000 feet of bedded tuffaceous and lignite-bearing sandstones and shales, to a large degree of estuarine or freshwater origin, but with frequent local zones of marine fossiliferous sediments, are involved in this folding.

Other areas of the Chehalis formation are the Balch syncline west of Chehalis and Centralia, the King County coal fields extending from Allentown in the Duwamish Valley eastward and southward beneath the glacial drift to Renton, Green River, Newcastle, and Squak Mountain, and the lowest 2,000 feet of Eocene in the Pierce County coal field, the beds in which the Fairfax and Montezuma mines are located.

No equivalent strata have been recognized elsewhere in the northwest but the Tejon of the type locality near old Fort Tejon in California evidently represents the same faunal stage. In many respects the Chehalis fauna is similar to that of the succeeding Olequa formation, but the floras are markedly different, that of the Chehalis formation lacking the distinctly tropical facies of the later divisions of the Tejon, and thus affording a most characteristic feature.

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[15] *Am. Geol.*, XIII., 1894, p. 437.

Excellent plant localities occur at Steel's Crossing near Allentown, the Fairfax and Montezuma mines on Carbon River, Delazine Creek near Elma, and Skookum Chuck Canon below Bucoda. The Taylor clay mine on Green River, Snoqualmie Pass, the Newcastle mine east of Lake Washington, and a point in the hills south of where the Centralia-Oakville fault crosses Lincoln Creek are also said to have contributed fossil plants belonging to this horizon.

The following marine invertebrate fauna has been obtained from the Chehalis formation.

The Olequa Formation.

Overlying the Chehalis beds is a horizon of the Tejon Series which on Olequa Creek in southern Lewis and northern Cowlitz counties, Washington, contains an excellent flora, and also marine and freshwater faunas. The type section extends from the Erwing ranch a little over two miles above Little Falls southward down Olequa Creek to Olequa, a distance of about five and one-half miles. The beds immediately below Erwing's represent a low east-west syncline in which marine beds are overlain by freshwater deposits, and these in turn by plant-bearing shales. Down the river a low anticlinal axis crosses Olequa Creek a little above Little Falls in the heart of which other freshwater and marine beds are exposed. At the railroad bridge below Little Falls the upper marine and freshwater beds reappear dipping southward and some distance above them in nearly horizontal strata appears a thin zone of coarse basalt tuff containing numerous marine fossils near the old railroad bridge above Olequa. From here southward the Eocene is mantled by Pliocene basalts associated with river gravels.

The same horizon of the Eocene reappears, however, at Castle Rock and farther west on Coal Creek above Stella in a more or less regular repetition of low folds with east-west axes. Probably the total thickness of beds in this district does not represent more than 2,000 or 3,000 feet.

The flora is noteworthy for the abundance of a large palm, probably *Calamopsis* cf. *danae* Lx. and of *Magnolia* cf. *Californica* Lx. As both these species and one or two others identical with Olequa

Partial List of Species in the Chehalis Horizon of the Tejon Series (Middle Eocene) on the Cowlitz River and Bordering the Chehalis Valley, Washington.

	57	58	113	145
PELECYPODA:				
Avicula pellucida Gabb	......	......	×	......
Cardium breweri Gabb	......	×	×	......
Corbula horni Gabb	......	×	×	......
Crassitellites compacta Gabb	......	......	×	......
Crassitellites grandis Gabb	×	......	......	......
Crassitellites uvasana Conr	......	......	×	......
Macrocallista conradiana Gabb	......	×	......	......
Marcia quadrata Gabb	......	......	×	......
Meretrix californica Conr.[16]	×	......	......	×
Meretrix horni Gabb	×	×	×	......
Meretrix ovalis Gabb	×	......	......	......
Meretrix uvasana Conr	......	......	......	×
Miltha turneri Stanton	×	......	......	......
Modiolus ornatus Gabb	×	×	......	......
Ostrea idriænsis Gabb	×	×	×	......
Solen parallelus Gabb	×	×	......	......
Tellina horni Gabb	......	......	×	......
Tellina longa Gabb	×	......	×	......
Tellina remondi Gabb	×	......	......	......
Venericardia horni Gabb[16]	×	×	×	......
GASTEROPODA:				
Amauropsis alveata Conr	......	......	×	......
Ancillaria bretzi Wvr	......	......	×	......
Calyptræa excentrica Gabb	×	×	×	......
Conus remondi Gabb[16]	......	......	×	......
Crepidula pileum Gabb	......	×	×	......
Exilia diabloi Gabb[16]	......	......	×	......
Ficopsis horni Gabb	......	......	×	×
Gyrineum washingtonianum Wvr	......	......	×	......
Mitra washingtoniana Wvr	......	......	×	......
Morio tuberculatus Gabb	......	......	×	×
Murex sopenahensis Wvr	......	......	×	......
Olivella mathewsoni Gabb	......	......	×	......
Perissolax washingtoniana Wvr[16]	......	×	×	×
Polinices horni Gabb	×	×	×	×
Polinices secta Gabb	......	×	×	......
Pseudoliva volutæformis Gabb	......	×	......	......
Rimella simplex Gabb	......	......	×	......
Sinum obliquum Gabb	×	×	×	......
Strepsidura whitneyi Gabb	×	......	×	......
Thais eocenica Wvr	......	......	×	......
Tritonium cowlitzense Wvr	......	......	×	......
Turris fresnoensis Arn	......	......	×	......
Turris io Gabb	......	......	×	......
Turris sinuata Gabb[16]	......	......	×	×
Turritella uvasana Conr	×	×	×	×
SCAPHOPODA:				
Dentalium cooperi Gabb	......	×	......	×
Dentalium stramineum Gabb	×	×	×	×
CEPHALOPODA:				
Aturia mathewsoni Gabb	......	......	×	......

---

[16] Species supposed to be characteristic of this horizon.

Locality 57; sandstone, cuts along O. W.-Milwaukee Railway east of Balch, Washington. (H. Hannibal.)

Locality 58; shaly sandstone, bluffs along Olequa Creek at old Ainslee Mill below Winlock, Washington. (H. Hannibal.)

Locality 113; shaly sandstone, bluffs along Cowlitz River below mouth of Drew Creek, 1½ miles east of Olequa, Washington. (H. Hannibal.)

Locality 145; shaly sandstone, water-tunnel on hill east of Chehalis, Washington. (H. Hannibal.)

Partial List of Species in the Olequa Horizon of the Tejon Series (Middle Eocene) at Little Falls, Washington.

	65	66	68	70	73	74	75
PELECYPODA:							
Avicula pellucida Gabb	...	...	×	...	...	...	...
Barbatia morsei Gabb	×	...	×	...	...	×	...
Cardium breweri Gabb	×	×	...	...	×	...	...
Cardium olequæensis Wvr.[17]	...	×	×	×	...	×	...
Crassitellites compacta Gabb	...	...	...	...	...	×	...
Crassitellites grandis Gabb	...	...	...	×	...	...	...
Crassitellites washingtoniana Wvr.[17]	...	...	×	...	×	...	...
Cyrena brevidens White	...	...	×	...	...	...	...
Macrocallista conradiana Gabb	×	...	×	×	...	...	...
Marcia quadrata Gabb	×	...	...	...	...	...	...
Modiolus ornatus Gabb	×	...	...	×	×	...	...
Ostrea idriænsis Gabb	×	×	×	×	...	×	×
Pecten landesi Arn.[17]	...	×	...	×	...	...	...
Septifer dicrotomus Gabb	...	...	...	×	...	...	...
Solen parallelus Gabb	...	×	...	...	×	...	...
Tellina horni Gabb	...	×	...	...	...	...	...
Venericardia horni Gabb[17]	×	×	×	...	×	×	×
GASTEROPODA:							
Amauropsis alveata Conr.	×	×	...	...	×	...	...
Calyptræa excentrica Gabb	×	...	×	×	×	...	×
Ficopsis horni Gabb	×	×	...	×	×	...	...
Ficus mamillatus Gabb	...	×	...	...	...	...	...
Polinices horni Gabb	...	×	×	×	...	...	...
Polinices secta Gabb	...	×	×	...	×	...	...
Pseudoliva volutæformis Gabb	...	×	...	...	×	...	...
Rimella simplex Gabb	×	×	...	×	...	...	...
Sinum obliquum Gabb	...	×	×	...	...	...	...
Turritella uvasana Conr	×	...	×	×	×	×	...
SCAPHOPODA:							
Dentalium cooperi Gabb	...	...	×	...	...	...	...
Dentalium stramineum Gabb	×	×	×	...	...	...	...

---

[17] Species supposed to be characteristic of this horizon.

Locality 65; sandstone, bluffs along Olequa Creek between falls and town, Little Falls, Washington. (H. Hannibal.)

Locality 66; tuffaceous sandstone, bluffs at junction of Olequa and Stillwater Creeks, Little Falls, Washington. (H. Hannibal.)

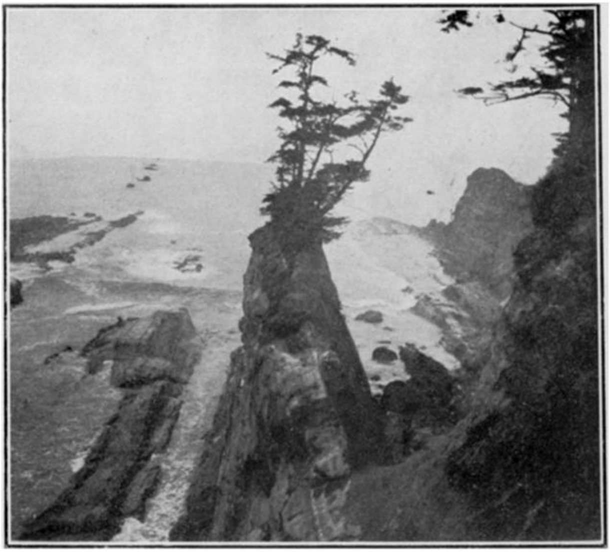

FIG. A.

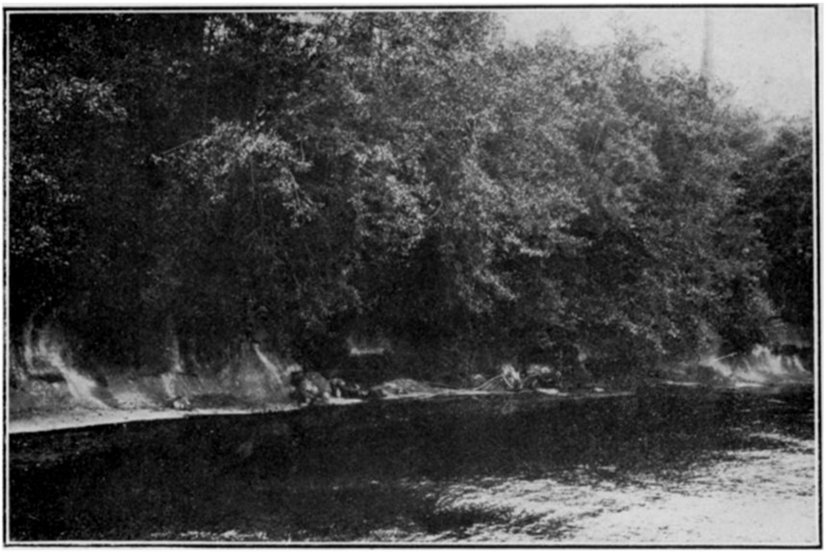

FIG. B.

FIG. A. Steeply tilted Arago beds (Tejon series) at Mussel Reef west of Coos Bay, Oregon.

FIG. B. Olequa beds (Tejon series) near old log dam on Stillwater Creek, Little Falls, Washington.

Locality 68; sandstone and tuffaceous marl, bluffs on Stillwater Creek at old logdam and for one fourth of a mile below, Little Falls, Washington (H. Hannibal.)

Locality 70; tuffaceous sandstone, bluffs along Stillwater Creek three fourths of a mile west of junction with Olequa Creek, Little Falls, Washington. (H. Hannibal.)

Locality 73; basalt tuff, cut on Portland-Tacoma railway two and one half miles south of Little Falls, Washington. (H. Hannibal.)

Locality 74; sandstone, gulch below Backstrom ranch, Brim Creek, Little Falls, Washington. (H. Hannibal.)

Locality 75; lignitic sandstone, bluffs three fourths of a mile above Con Murphy ranch on Stillwater Creek, Little Falls, Washington. (H. Hannibal.)

forms are present in the Swauk formation at Liberty, Washington, it is probable that the two deposits on opposite sides of the Cascade Mountains are approximately contemporaneous.

An excellent plant locality in the Olequa formation occurs on Olequa Creek above Little Falls, another is situated in the hills west of Castle Rock. The plant localities at the Carbonado and Wilkeston coal mines, South Prairie Creek above the Burnett Mine, the Bellingham and Lake Whatcom mines, and near Maple Falls on Mt. Baker may be referable to this horizon.

The following marine fauna was collected on Olequa and Stillwater Creeks near Little Falls.

Arago Formation.

The type section of the Arago formation[18] is taken across the strike of a steeply tilted fault-block which may be estimated to include approximately 10,000 feet of alternating marine and freshwater sediments, partly arkose and partly tuffaceous in character, without the base or top of the formation being exposed. A much larger area in which more than 15,000 feet of sediments are represented extends eastward from Coos Bay to the base of the Cascade Mountains and northward along the west flank of the Cascades and through the heart of the Coast Range, besides underlying and outcropping in the Willamette Valley across which the formation was once continuous. In the northward extension of the Arago in Oregon the sedimentary deposits become more and more replaced by basic volcanic flows and agglomerates, until on the Santiam River east of Albany and the Nehalem River in Clatsop and Columbia Counties only igneous rocks are present, the few fragmentary fossils on which the determination of the age of these lavas is based being obtained from coarse tuffs.

---

[18] See J. S. Diller, Coos Bay Folio, No. 73, U. S. Geol. Sur., 1901.

Partial List of Species in the Arago Horizon of the Tejon Series (Middle Eocene) of Southwestern Oregon and the North Coast of Washington.

	32	33	40	99	116	154
PELECYPODA:						
Cardium breweri Gabb	...	...	...	×	×	...
Cardium cooperi Gabb	...	...	...	×	...	...
Corbula horni Gabb	...	...	...	×	×	...
Crassitellites compacta Gabb	...	...	...	×	...	...
Crassitellites uvasana Conr	×	...	...	×	...	...
Cyrena brevidens White	...	×	...	...	...	...
Glycymeris cor Gabb[21]	...	...	...	×	×	...
Macrocallista conradiana Gabb	×	...	...	×	×	...
Marcia quadrata Gabb	...	...	...	...	×	...
Meretrix horni Gabb	...	×	...	...	...	...
Miltha turneri Stanton	...	×	...	...	...	...
Modiolus ornatus Gabb	×	×	...	×	×	...
Ostrea idriaensis Gabb	...	×	...	×	×	×
Septifer dichrotomus Gabb	...	...	...	...	×	...
Solen parallelus Gabb	×	...	...	×	...	...
Tellina horni Gabb	×	...	...	...	...	...
Tellina longa Gabb	...	×	...	...	...	...
Tellina remondi Gabb	×	×	...	...	...	...
Venericardia horni Gabb (var. with obsolete ribs)[19]	×	...	...	×	×	×
GASTEROPODA:						
Amauropsis alveata Conr	...	...	...	×	×	...
Calyptræa excentrica Gabb	...	...	...	×	×	...
Conus sinuatus Gabb	...	...	...	×	...	...
Ficopsis horni Gabb	×	...	...	×	...	...
Loxotrema turrita Gabb	...	...	...	×	...	...
Olivella mathewsoni Gabb	...	...	...	×	...	...
Polinices globosa Gabb[21]	...	...	...	...	×	...
Polinices horni Gabb	×	...	...	...	...	...
Polinices shumardiana Gabb[21]	...	...	...	×	×	...
Potamides carbonicola Cooper[21]	...	...	...	×	...	...
Sinum obliquum Gabb	×	...	...	...	...	...
Strepsidura whitneyi Gabb	×	×	...	...	...	...
Tritonium californicum Gabb	...	...	...	...	×	...
Turris io Gabb	×	...	...	...	...	...
Turritella uvasana Conr	×	...	×	×	×	...
SCAPHOPODA:						
Dentalium stramineum Gabb	×	×	...	...	...	...
BRACHIOPODA:						
Terebratulina tejonensis Stanton	...	...	...	...	...	×

---

[19] Species supposed to be characteristic of this horizon.

Locality 32; sandstone and shale, seacliffs between mouth of Big Creek and Cape Gregory, Coos Bay, Oregon. (H. Hannibal.)

Locality 33; sandstone and shale, seacliffs at Mussel Reef between Coos Head and Cape Gregory, Coos Bay, Oregon. (H. Hannibal.)

Locality 40; sandstone, one fourth of a mile below top of grade north of Five-mile Creek, Bandon, Oregon. (H. Hannibal.)

Locality 99; tuffaceous sandstone, bluffs along Little River at junction with north fork of Umpqua River, Glide, Oregon. (H. Hannibal.)

Locality 116; basalt tuff, seacliffs between pier and Point Crescent, Port Crescent, Washington. (H. Hannibal.)

Locality 154; basalt tuffs, seacliffs immediately southwest of Tongue Point, Port Crescent, Washington. (H. Hannibal.)

On the north coast of Washington the senior author[20] has termed a series of coarse heavy-bedded basalt tuffs with intercalated flows and a minor element of sandstone the Crescent formation. Collections of fossils from the tuff and sandstone obtained by the junior author in 1912 indicate that this formation is the stratigraphic equivalent of the Arago.

The Benton County hills a mile north of Granger, Oregon, Mary's Peak near Philomath, the Willamette River above Springfield, and the north Santiam River between Lyons and Kingston have yielded excellent plant remains pertaining to this horizon, usually in a white or pink rhyolite tuff intercalated with the basalts. Knowlton[21] has also described plants from a locality in the Arago near Comstock in Douglas County and another on Coal Creek in Lane County. Several near Ashland may represent the same horizon.

The following fauna was obtained from the type section south of Coos Bay and from points on the Umpqua River, Oregon, and the north coast of Washington.

OLIGOCENE DEPOSITS—THE STATUS OF THE OLIGOCENE OF THE PACIFIC COAST.

Until a comparatively few years ago the tertiary of the Pacific Coast was classified on a three-fold basis—Eocene, Miocene and Pliocene, and the term Oligocene was a vague indefinite division recognized by European geologists, but no equivalent strata were known on the Pacific Coast. In 1898 Dall[22] used the term Oligocene for the first time in connection with Pacific Coast stratigraphy to cover the "*Aturia* bed," Astoria shales, and doubtfully (and correctly so since it is not a homogenous formation) the Tunnel Point beds of the Oregon Coast. Following this the senior writer[23] placed the San Lorenzo formation of California in the Oligocene on the basis of its equivalence to strata referred to that period on the north Pacific Coast.

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[20] Arnold, R., *Bull. Geol. Soc. Am.*, XVII., 1906, p. 460.

[21] 20th Ann. Rept. U. S. Geol. Sur., Pt. III., 1900, pp. 37–64, Pl. I.–V.; Bull. 204, U. S. Geol. Sur., 1902, p. 111.

Were the Pacific Coast Tertiary the standard for the world it is obvious that a three-fold division would be recognized. The lowest member would consist of the Martinez and Tejon, equivalent to the present Eocene. The succeeding division would embrace the Sooke, Astoria, Vaqueros, and Monterey and correspond to what has been commonly called Oligocene and Lower Miocene. The third would include the numerous usually local formations of which the Empire is the oldest and the Elk River and Deadman Island or Santa Barbara Pliocene the youngest, in other words the middle and upper Miocene and Pliocene, there being no well-marked hiatus in this part of the world between beds of Miocene and Pliocene age, as these divisions are currently recognized.

A direct correlation between the Pacific Coast marine Tertiary and the deposits of Europe and bordering the Gulf of Mexico is impossible owing to the almost total absence of identical species except in the Eocene. The nummulites and corals which have been depended upon to establish the contemporaneity of the Oligocene of Europe and the Antilles are not known on the Pacific Coast, and there do not appear to be any other forms that will serve the purpose. However an assumption that approximately the same time interval is represented by the Pacific Coast deposits may be based on certain broad resemblances.

In the closely allied succession of strata commencing with the Sooke and terminating with the Monterey, the oldest beds lack so far as known any recent species of mollusca while the number gradually increases to about 6 per cent. of the fauna in the Monterey. The proportion of species extending from the Monterey into the Middle Miocene is somewhat greater—perhaps 25 per cent. Two or three long-lived species known in the Eocene range through the entire Sooke-Monterey succession. With two notable exceptions, the Sooke and Twin River formations, this entire succession is decidedly subtropical in facies. There is a conspicuous element of distinctly Eocene-Oligocene genera throughout, such as *Crassitellites, Aturia, Molopophorus, Exilia, Perissolax, Priscofusus, Strepsidura,* and giant Turritellas, associated with an exceptionally large number of species of *Turris, Patella, Barbatia, Macrocallista, Eudolium,* giant Limas, and other usually tropical genera unknown or of exceptional occurrence in the later deposits of the district.

---

[22] "A Table of North American Tertiary Horizons Correlated with One Another and Those of Western Europe with Annotations," 18th Ann. Rept. U. S. Geol. Sur. (II.), 1898, p. 323–348.

[23] Prof. Pap. 47, U. S. Geol. Sur., 1906, p. 15 ff.

This Oligocene facies of the fauna is very obvious in the Sooke and Astoria, but less marked in the Vaqueros owing to the additional presence of *Lyropecten* and giant Ostreas, typical Miocene types which, however, must have had their beginning in earlier strata to have become so widespread and important an element of the Miocene fauna. The Monterey is faunally closely allied to these other beds by numerous identical species, but as far as our present knowledge goes, might be placed equally well in the latest Oligocene or the earliest Miocene on the basis of the general faunal facies.

THE SOOKE FORMATION.

Occupying several disconnected areas along the south coast of Vancouver Island from Becher Bay westward to Sombrio River near Port San Juan and perhaps farther, is a formation originally described as probably upper Miocene owing to the boreal type of fauna. This Merriam[24] has termed the Sooke beds. With the exception of the type area between Muir and Coal Creeks several miles west of Sooke where drillings have shown the sediments to be more than 1,500 feet thick, the beds comprise only a few feet of basal conglomerate usually less than the height of the sea cliffs in thickness. These lie directly on the bedrock complex, the Vancouver greenstone-diorites, and on Muir Creek a mile or two back from the coast the greenstone is exposed beneath the Sooke in the bed of the Cañon so that the development of the sedimentaries on the coast is evidently only local.

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[24] Bull. Dept. Geol. Univ. Cal., II., 1896, p. 101–8.

The following fauna was obtained from this formation.

Partial List of Species in the Sooke Formation (Middle Oligocene) of the Southern Coast of Vancouver Island.

	129	130	131
PELECYPODA:			
Macrocallista mathewsoni Gabb.	×	....	×
Macrocallista newcombei Mrm.[24a]	×	....	....
Mytilus sammamishensis Wvr	×	×	×
Ostrea idriæensis Gabb.	×	×	×
Pecten branneri Arn.[24a]	×	×	×
Phacoides acutilineatus Conr	....	....	×
Solen curtus Conr	×	....	....
Spisula albaria Conr	×	....	....
Tellina oregonensis Conr	×	×	×
Yoldia oregona Shum	×	....	....
GASTEROPODA:			
Alectryon newcombei Mrm.[24a]	×	×	×
Bullia buccinoides Mrm	×	×	....
Crepidula prærupta Conr.	×	....	....
Eudolium petrosum Conr.	×	....	....
Natica oregonensis Conr	×	×	....
Patella geometrica Mrm.[24a]	×	×	....
Polinices callosa Gabb	×	....	....
Polinices galianoi Dall	×	×	....
SCAPHOPODA:			
Dentalium conradi Dall	....	....	×

[24a] Species characteristic of this horizon.

Locality 129; sandstone and conglomerate, seacliffs between Muir and Coal Creeks west of Otter Point, Sooke, Vancouver Island. (C. F. Newcombe and H. Hannibal.)

Locality 130; basal sandstone, seacliffs at Fossil Creek, two miles west of Sherringham Point, Jordan River, Vancouver Island. (H. Hannibal.)

Locality 131; basal sandstone, seacliffs one half of a mile east of Slide Hill telegraph station, Jordan River, Vancouver Island. (H. Hannibal.)

THE ASTORIA SERIES.

The name Astoria formation as applied to a stratigraphic division of the Oregon Tertiary was first used in print by Cope[25] who says "the unpublished notes of Prof. Condon, formerly State Geologist, state that the backbone of the Coast Range consists of argillaceous shales, which contain invertebrate and vertebrate fossils, frequently in concretions. Some of the latter are Physoclostous fishes with strongly ctenoid scales. To this formation, Dr. Condon gives the name of *Astoria Shales*. Above this is an extensive Tertiary deposit rich in Mollusca, which is usually interrupted by the central elevations of the mountain axis. Prof. Condon refers this to an Upper Miocene age under the name of the *Solen* beds."

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[25] *Am. Nat.*, XIV., 1880, p. 457.

As in the instance of other Tertiary formations named before the modern exact method of describing a type section or area and basing a formation on it came into use, the definition of the Astoria Shales is vague, and has led to the inclusion under that name of nearly all the Lower Miocene-Oligocene of northwestern Oregon in spite of unconfirmed suspicions on the part of several California geologists that more than one horizon was represented there. Under the circumstances it is desirable to go back and see what Condon intended the name to cover.

At the time of Hannibal's visit in 1911 the sequence of faunas and range of species in the North Pacific Coast Oligocene and Lower Miocene were not understood, and except for keeping the material from the several localities at Astoria separate no attempt was made to work out the stratigraphy and it was not until the excellent sections exposed along both coasts of the Straits of Fuca were carefully collected in during the spring and summer of 1912 that a definite clue to the presence of two formations at Astoria was obtained. A second visit was paid to the section there during that summer, and later, through the courtesy of Prof. Collier, Condon's collection at the University of Oregon was briefly examined with the idea of deciding what Condon intended the "Astoria Shales" and "*Solen* beds" to include.

From the Astoria Shales there is in the Condon collection a quantity of invertebrate material and fish remains[26] largely incased in gray limestone concretions, and derived without doubt from the low westward dipping monocline of ashy shales which extends from above Tongue Point, several miles up the Columbia River, to Smith Point below the city, forming an unbroken bluff back of the town beneath the scattered areas of Pliocene basalt. Most of the distance these shales reach down to the water's edge and quantities of round or kidney shaped gray limestone concretions are washed out of them by the combined action of the tide and river currents. Practically the entire succession of beds in this monocline represent the Seattle horizon and it is probable that this is what Condon intended to be his type section if he had any specific section in mind. However, the collections and description indicate that he also intended to include in the Astoria the San Lorenzo Shales of Clatsop and Columbia counties which conformably underlie the Seattle beds, and make up to a much greater degree the sedimentary portion of the backbone of the Oregon Coast Range.

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[26] See the forms figured in the Atlas Geol. Wilke's Expl. Exp., 1849, Pl. XVI.-XVII.

The "*Solen* beds" evidently comprised three things, the Empire sandstone of the Coos Bay district with *Solen sicarius* Gld., the sandstones with *Solen curtus* Conr. at the foot of 19th Street at Astoria, unconformable on the Astoria Series and from the accompanying fauna evidently Monterey,[27] and the basal San Lorenzo tuffs at Smith's quarry near Eugene with *Solen curtus* Conr. As this last locality is isolated from the main Astoria area and the fauna is quite distinct from that in any of the shales of the Astoria, though the difference is entirely the result of the character of the bottom at the time the beds were laid down, it is not surprising that Condon should have supposed it to represent a horizon nearer to the Monerey locality at Astoria which contains one or two common species.

The writers propose therefore to use the name Astoria Series, not in a loose sense for all the Oligocene-Lower Miocene of western Oregon but as a general name for the conformable sequence of beds here divided on palaeontological evidence into two horizons, the San Lorenzo and Seattle formations. To these are added on the north coast of Washington a third division, soft semicoherent beds everywhere else removed by erosion before the deposition of the Monterey, the Twin River formation.

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[27] See list from here in connection with the description of the Monterey formation.

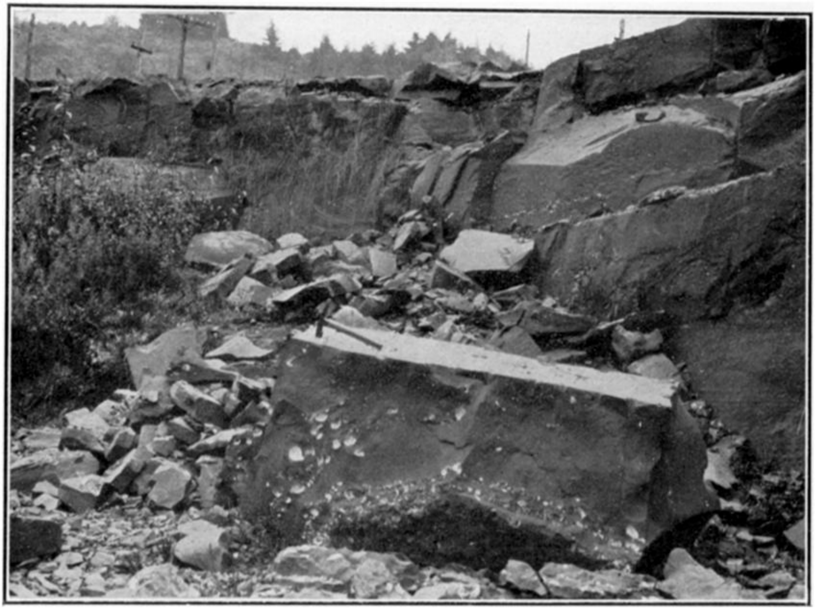

FIG. A.

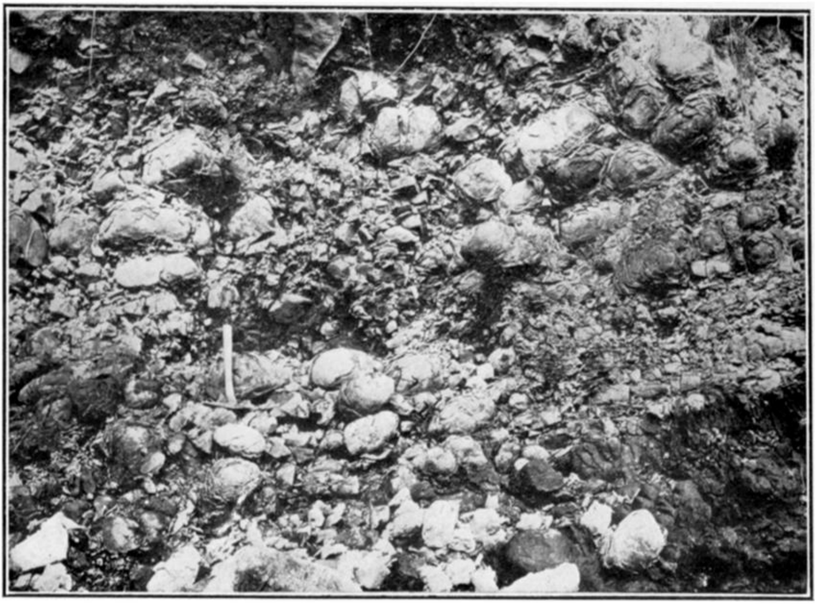

FIG. B.

FIG. A. Tuffaceous San Lorenzo sandstone (Astoria series) at old Smith Quarry, Eugene, Oregon.

FIG. B. Weathered basic tuffs interbedded in San Lorenzo formation (Astoria series) on Vance Creek southwest of Union City, Washington.

Astoria Series	Twin River formation (zone of *Acila gettysburgensis* Rgn., *Turritella oregonensis* Conr., and *Polinices olympidii* Rgn.).
	Seattle formation (zone of *Acila gettysburgensis* Rgn., *Turcicula washingtoniana* Dall, *Turritella newcombei* Mrm., and *Macrocallista vespertina* Conr.).
	San Lorenzo formation (zone of *Acila shumardi* Dall and *dalli* Arn., *Turritella newcombei* Mrm., *Turcicula columbiana* Dall, and *Macrocallista pittsburgensis* Dall).

The average thickness of the Astoria Series is not less than 12,000 feet, but at some points it attains a much greater development. In the Cape Flattery section about 17,000 feet of apparently conformable coarse sandstones and conglomerates, derived largely from the bedrock series of Vancouver Island, from their fossil contents appear to belong exclusively to the San Lorenzo horizon. The base of the section is cut off by faulting at the mouth of the Soo-es River while the uppermost beds pitch beneath the waters of the Straits of Fuca. Between Winlock and Shoalwater Bay, also in Washington, is a monotonous westward dipping succession of the Astoria Series which if aggregated would total more than 50,000 feet of beds. The paucity of outcrops and the recurrence of certain igneous flows and tuffs associated with the same basal San Lorenzo fauna suggests the presence of a repetition by step faulting which, with the limited time spent in this district of heavy forests, it was impractical to trace out.

The San Lorenzo Formation.

The name San Lorenzo formation has been used by the senior writer[28] for a series of sandstones and diatomaceous shales in the Santa Cruz Mountains, California. Nearly the entire San Lorenzo fauna reappears at a definite horizon in the Tertiary of the North Pacific Coast, *i. e.*, the lowest faunal division of the Astoria Series.

[28] Prof. Pap. 47, U. S. Geol. Sur., 1906, p. 16; Santa Cruz Folio No. 163, U. S. Geol. Sur., 1909; *Proc. U. S. Nat. Mus.*, XXXIV., No. 1617, 1908, p. 348.

It is therefore convenient to use the name San Lorenzo here as well as in California.

On the North Pacific Coast the San Lorenzo ordinarily consists of two members; a basal sandstone and conglomerate varying from 10 to 500 feet or more in thickness and composed largely of worked over volcanic ejectmenta, lying on the basalt or andesite flow which at many points marked the opening of the Astoria epoch, or directly on older rocks; and a shale member several thousand feet thick ordinarily arenaceous, gray and massive, less frequently ashy and dark colored, or calcareous and bluish. Seen under the microscope this shale is composed largely of fine volcanic detritus and has little of the organic character of the San Lorenzo shale of California.

The principal areas of the San Lorenzo formation on Vancouver Island form the narrow intermittent strip of Oligocene sandstones and shales bordering the southwest coast from Sombrio River west to Barkley Sound. In Washington the conglomerates of the Cape Flattery section and eastward to Shroud Head; the sandstones and shales overlying the Oligocene basalts and andesites south and west of Port Townsend; the sandstones overlying the lower Astoria basalts west of Port Orchard Sound and forming the lower half of the Bainbridge Island section of the Seattle Monocline; the shales overlying the basal Astoria basalts north and east of Oakville, Porter, and Elma; the lowest Oligocene exposed in the Lincoln Creek section; and a large part of the monocline previously mentioned as occurring west of Winlock including the Winlock, Pe Ell, Holcomb, Skamokawa and Upper Nasel River exposures are noteworthy. In Oregon the Astoria shales south of the Columbia River at Clatskanie, Scapoose, the upper Nehalem Valley, and West Dairy Creek, isolated exposures about the borders of the Willamette Valley at Silverton, McCoy, and overlying the Eocene basalts at Eugene and Springfield, the lowest beds of the westward dipping monocline between Blodgett and Newport, and the steeply dipping section exposed in the seacliffs south of the entrance to Coos Bay between Basendorfs (Miner's Flat) and Tunnel Point should be regarded as contemporaneous. The so-called Pliocene of the Yahates River belongs also to this horizon.

A typical San Lorenzo fauna has been collected from the area north and east of Porter, Washington.

Partial List of Species in the San Lorenzo Horizon of the Astoria Series (Middle Oligocene) of the Porter-Oakville District, Washington.

	50	51	52	53	54	55	56	109	207
PELECYPODA:									
Cardium lorenzoanum Arn	×	×	×	×	×	...	×	...	...
Crenella porterensis Wvr	×	...	×	×	×	...	...	...	...
Ervilia oregonensis Dall[29]	...	×	...	...	...	...	...	...	...
Macrocallista mathewsoni Gabb	...	...	...	...	...	...	...	×	...
Macrocallista pittsburgensis Dall[29]	...	...	...	×	...	...	...	...	...
Malletia chehalisensis Arn.[29]	×	...	...	×	...	...	...	...	...
Marcia oregonensis Conr.[30]	×	...	...	...	...	...	...	...	...
Ostrea idriæensis Gabb	...	×	...	...	...	...	...	...	...
Pecten branneri Arn.[29] (*P. proavus* Arn., *P. washburnei* Arn.)	...	×	...	...	...	...	...	×	...
Pecten peckhami Gabb	...	...	×	...	×	×	...	...	×
Semele gayi Arn.[29]	...	×	...	...	...	...	...	...	...
Thracia trapezoidea Conr	...	...	...	×	...	...	...	...	...
Thyasira bisecta Conr.[30]	...	...	...	×	...	...	...	...	...
Yoldia impressa Conr	×	×	...	×	...	...	...	...	×
GASTEROPODA:									
Epitonium rugiferum Dall[29]	...	×	...	...	...	...	...	...	...
Hipponyx carpenteri Arn.[29]	...	×	...	...	...	...	...	...	...
Molopophorus gabbi Dall[29]	...	...	...	...	...	...	...	×	...
Patella mateoensis Arn.[29]	...	×	...	...	...	...	...	...	...
Turcicula columbiana Dall[29]	...	...	...	...	×	...	...	×	...
Priscofusus hecoxi Arn.[29]	×	...	...	×	×	...	×	×	...
Priscofusus sanctæcrucis Arn.[29]	...	×	...	...	...	...	...	...	...
Turritella newcombei Mrm.[29]	×	×	×	×	×	×	×	...	...
SCAPHOPODA:									
Dentalium conradi Dall	×	×	×	×	×	×	×	...	×
CEPHALOPODA:									
Aturia angustata Conr	...	...	...	...	...	...	...	...	×
BRACHIOPODA:									
Terebratalia occidentalis Dall[30]	...	×	...	...	...	...	...	×	...
Terebratulina caputserpentis L.[30]	...	×	...	...	...	...	...	×	...
ECHINODERMATA:									
Cidaris merriami Arn.[29]	...	...	...	...	...	...	...	...	×

NOTE.—*Thracia condoni* Dall, *Acila cordata* Dall, *dalli* Arn. and *shumardi* Dall, *Strepsidura californica* Arn. (*S. oregonensis* Dall), *Epitonium condoni* Dall and *rugiferum* Dall, and *Miopleionia indurata* Conr. are also characteristic species of this horizon.

Locality 50; massive shaly sandstone, road cuts one fourth of a mile southeast of Porter along Chehalis River, Washington. (H. Hannibal.)

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[29] Species characteristic of this horizon.

[30] Species still living.

Locality 51; basal marly tuffs, bluffs at old logdam on Porter Creek one and one half miles above Porter, Washington. (H. Hannibal.)

Locality 52; massive shaly sandstone, bluffs one fourth of a mile below logdam on Porter Creek, Porter, Washington. (H. Hannibal.)

Locality 53; massive shaly sandstone, bluff on Chehalis River below Porter, Washington. (H. Hannibal.)

Locality 54; massive shaly sandstone, bluffs along Porter Creek three fourths of a mile above Porter, Washington. (H. Hannibal.)

Locality 55; massive shaly sandstone, cut on Lytle logging R. R. near top of ridge one mile above switch, Porter, Washington. (H. Hannibal.)

Locality 56; massive shaly sandstone, bluffs along Porter Creek one mile above old logdam, Porter, Washington. (H. Hannibal.)

Locality 109; basal tuffaceous conglomerate, beds immediately overlying basalt at quarry on N. P. R. R., one mile west of Oakville, Washington. (H. Hannibal.)

Locality 207; tuffaceous shale, bluffs along Vances Creek two and one half miles above junction with Skokomish River and thirteen miles above Union City, Washington. (Thos. Purdy, Ed. McCreavy, and H. Hannibal.)

The Seattle Formation.

In the sections at Gettysburg, Bainbridge Island, Lincoln Creek, Nasel River, Nehalem River, Yaquina River, and several other points the San Lorenzo formation is overlain conformably by a succession of beds usually finer grained, thinner bedded, and more calcareous, though the exceptions are too numerous to mention, containing a rather different fauna of less distinctly tropical type and a forerunner of the boreal Twin River fauna which succeeded it. The most fossiliferous exposures of this formation are in the upper beds of the northward dipping Seattle monocline extending from Restoration Point on Bainbridge Island across Admiralty inlet to Alki Point, Georgetown, and Columbia City in Seattle and reappearing east of Lake Washington near the mouth of Coal Creek below Newcastle. The maximum thickness is exposed on Bainbridge Island and aggregates perhaps 3,000 or 4,000 feet of beds.

Other exposures are to be found in Washington on the north coast east of Gettysburg and at the mouth of the Sekiu River, in the uppermost Oligocene beds of the Lincoln Creek section, the beds unconformable beneath the Monterey sandstone south of Elma on Delazine Creek, the lower Nasel River and Ilwaco Sections, and the bluffs at Grays River. In Oregon the Astoria Section, the beds at Nehalem Harbor, and those about the head of Yaquina Bay are contemporaneous.

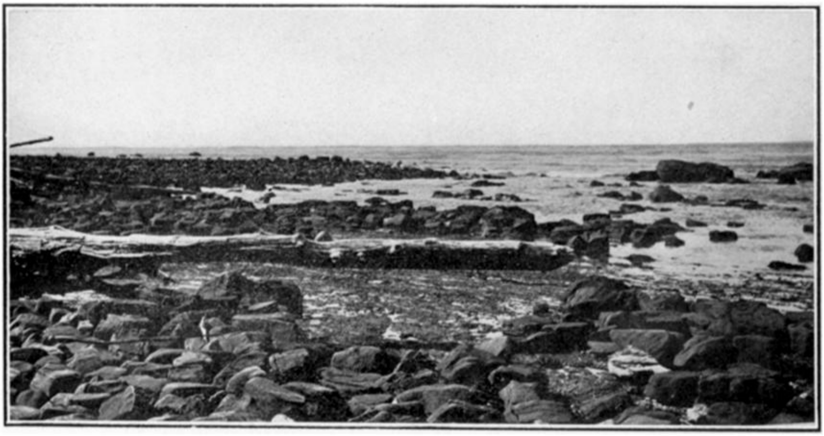

FIG. A.

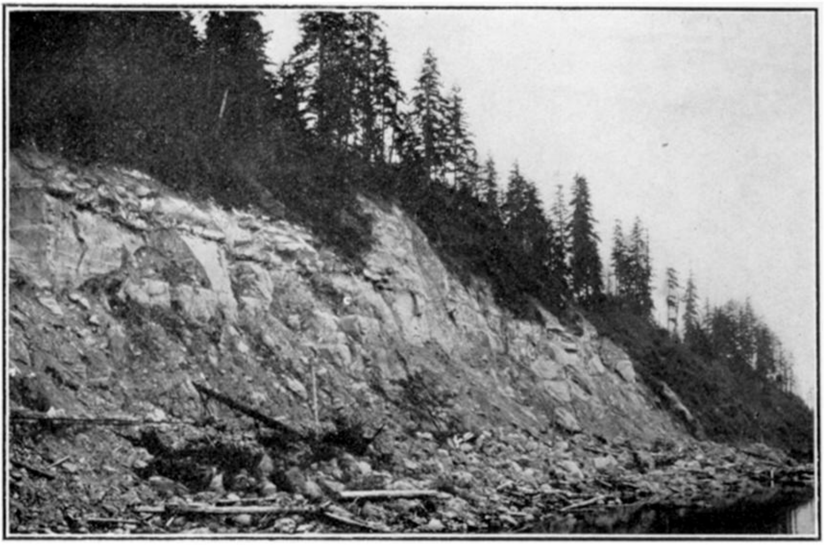

FIG. B.

FIG. A. Riprap beach formed from thin sandstone beds intercalated with Seattle shales at mouth of Sekiu River, north coast of Washington.

FIG. B. Massive tuffaceous San Lorenzo shales (Astoria series) on Chehalis River at Lincoln Creek, Washington.

The following fauna was obtained from the Seattle Monocline and at Astoria.

Partial List of Species in the Seattle Horizon of the Astoria Series (Middle Oligocene) of Seattle District, Washington and at Astoria, Oregon.

	Oregon			Washington				
	46	47	273	48	49	103	206	261
PELECYPODA:								
Acila gettysburgensis Rgn.[31]	...	...	×	×	×	×	...	×
Cardium lorenzoanum Arn	...	...	...	×	...	×	...	...
Crenella porterensis Wvr.[31]	...	...	...	×	...	×	×	...
Limopsis nitens Conr.[31]	×	...	...	...	...	...	...	...
Macrocallista vespertina Conr.[31]	...	...	...	...	...	×	×	×
Marcia oregonensis Conr.[32]	...	...	...	×	×	×	...	×
Modiolus ynezianus Arn	...	...	...	×	...	×	...	...
Mytilus sammamishensis Wvr	...	...	...	...	...	...	×	...
Nucula townsendi Dall	...	...	...	...	...	×	...	...
Panope generosa Gld.[32]	...	...	...	...	...	...	×	×
Pecten peckhami Gabb	...	×	×	...	×	...	...	...
Pecten waylandi Arn.[31]	×	×	×	...	...	...	...	...
Phacoides acutilineatus Conr	...	...	...	×	×	×	×	...
Solemya ventricosa Conr.[31]	...	...	...	...	...	×	...	...
Solen curtus Conr	...	...	×	...	...	×	×	×
Spisula albaria Conr	...	...	...	...	...	...	×	...
Tellina lorenzoensis Arn. (*Macoma moliniana* Dall)[31]	...	...	...	×	×	×	×	...
Tellina obruta Conr	...	...	...	×	...	×	...	...
Tellina oregonensis Conr	...	...	...	×	...	...	×	×
Thracia trapezoidea Conr	...	...	...	...	...	×	...	...
Thyasira bisecta Conr.[32]	...	...	...	×	...	×	...	...
Venericardia castor Dall[31]	...	...	...	...	...	×	×	×
Yoldia impressa Conr	...	...	...	×	...	×	×	×
Yoldia oregona Shum	...	...	...	...	...	...	×	...
GASTEROPODA:								
Crepidula prœrupta Conr	...	...	...	...	...	×	×	×
Eudolium petrosum Conr	...	...	...	×	×	×	...	...
Miopleionia indurata Conr.[31]	×	...	...	...	...	×	...	...
Natica oregonensis Conr	...	...	...	×	×	×	...	...
Turcicula washingtoniana Dall[31]	...	...	×	×	×	×	...	...
Turritella newcombei Mrm.[31]	...	...	...	...	...	×	×	...
SCAPHOPODA:								
Dentalium conradi Dall	...	...	...	×	...	×	×	×
CEPHALOPODA:								
Aturia angustata Conr	...	...	×	×	...	×	...	...
BRACHIOPODA:								
Hemithyris astoriana Dall[31]	×	...	...	...	...	...	...	...

Locality 46; ashy shales with limestone nodules, beach at foot of 46th Street, Astoria, Oregon. (H. Hannibal.)

[31] Species characteristic of this horizon.

[32] Species still living.

Locality 47; ashy shales with limestone nodules, beach between foot of Hull Street and Smith Point, Astoria, Oregon. (H. Hannibal.)

Locality 273; ashy shale, bluff back of town between 1st and 13th Streets, Astoria, Oregon. (H. Hannibal.)

Locality 48; sandy shale, beach from Alki Point south one fourth of a mile along shore of Puget Sound, Seattle, Washington. (H. Hannibal.)

Locality 49; massive shale, railroad cuts between Argo and Georgetown Stations, Seattle, Washington. (H. Hannibal.)

Locality 103; shaly sandstone, beach between south side of entrance to Blakely Harbor and Restoration Point, Bainbridge Island, Washington. (H. Hannibal.)

Locality 206; sandstone, bluffs overlooking Andrews Bay, Lake Washington, three fourths of a mile east of Columbia City Station, Seattle, Washington. (H. Hannibal.)

Locality 261; sandstone, bluffs along Coal Creek three fourths of a mile above Lake Washington, Newcastle, Washington. (H. Hannibal.)

Twin River Formation.

Conformable above the Seattle beds in the section of the Astoria series between Port Crescent and Pysht River on the north coast

Partial List of Species in the Twin River Horizon of the Astoria Series (Middle Oligocene) of the North Coast of Washington.

	120	121	122	158	159
PELECYPODA:					
Acila gettysburgensis Rgn.[33]	X	X	X	......	X
Cardium lorenzoanum Arn.	X	......	X	......	......
Marcia oregonensis Conr. (*M. subdiaphana* Cpr.)[34]	X	......	......	......	......
Modiolus ynezianus Arn.	......	......	X	......	......
Mytilus sammamishensis Wvr.	X	......	......	......	......
Pecten peckhami Gabb.	......	......	......	......	X
Phacoides acutilineatus Conr.	X	......	X	......	......
Solen curtus Conr.	X	......	......	......	......
Tellina obruta Conr.	X	X	X	......	X
Thracia trapezoidea Conr.	X	......	......	......	......
Thyasira bisecta Conr.[34]	X	X	X	......	......
GASTEROPODA:					
Eudolium petrosum Conr.	X	......	X	......	X
Natica oregonensis Conr.	X	......	X	......	X
Polinices galianoi Dall.	......	......	......	X	......
Polinices olympidii Rgn.[33]	X	......	X	......	......
Sinum scopulosum Conr.	X	......	......	......	......
Turritella oregonensis Conr.[33]	X	......	X	......	......
SCAPHOPODA:					
Dentalium conradi Dall.	X	......	X	......	X
CEPHALOPODA:					
Aturia angustata Conr.	X	......	......	......	X

[33] Species characteristic of this horizon.

[34] Species still living.

Locality 120; clay shales, seacliffs west of Twin for a distance of three fourths of a mile along shore, Olympic Peninsula, Washington. (A. B. Reagan, H. Hannibal.)

Locality 121; clay shales and sandstone, seacliffs at Arc Reef Point two and one half miles west of Twin, Washington. (H. Hannibal.)

Locality 122; shaly sandstone, seacliffs one half to three miles east of Twin, Washington. (A. B. Reagan, H. Hannibal.)

Locality 158; sandstone and shale, seacliffs at small point west one mile from Deep Creek, Twin, Washington. (H. Hannibal.)

Locality 159; shale and sandstone, seacliffs one and one half miles east of Pillar Point, Twin, Washington. (H. Hannibal.)

of Washington and extending from about three miles east of Twin. River west nearly to Pysht Bay where it is faulted against the Monterey, is a stretch of soft clay-shales perhaps 2,000 feet thick intercalated with occasional thin beds of sandstone that wash out on the beach as flags. These beds, both shales and sandstone, contain a fauna of a marked boreal type. Most of the species are undescribed, but the few already known indicate that it is quite as closely allied to the Vaqueros and Monterey as to the San Lorenzo and Seattle faunas, yet sufficiently distinct from all of these.

The horizon is named from the locality where the best fossil collecting was obtained.

THE MONTEREY FORMATION (OLIGOCENE-MIOCENE).

The term "Monterey Shales" has long been current in the geological literature of California for the great series of diatomaceous shales first described by Blake[35] and Lawson[36] from Monterey in that state. While these deposits are particularly interesting to the oil geologist on account of their petroliferous character, their affinities have long been uncertain owing to the impoverished molluscan fauna. Dr. J. P. Smith[37] was probably the first writer to correctly interpret their relations, considering them as simply an off-shore facies of the beds variously called the Upper Vaqueros, Temblor, *Agasoma* zone, and *Turritella ocoyana* beds. Recently the junior writer visited the type section and had no difficulty in securing a small but characteristic fauna from limestone lenses intercalated in the diatomaceous shales.

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[35] Blake, W. P., *Proc. Phila. Acad. Nat. Sci.,* VII., 1855, p. 328–331.

[36] Lawson, A. C., *Bull. Geol. Univ. Cal.,* I., 1893, p. 22.

[37] *Proc. Cal. Acad. Sci.* (4th Ser.), III., 1912, p. 161–182.

Partial List of Species in the Monterey Formation (Oligocene-Miocene) Between Monterey and Carmel, California.

PELECYPODA:
- *Arca devincta* Conr. (*A. montereyana* Osmont).[38]
- *Leda taphria* Dall.[39]
- *Leda penita* Conr.[38]
- *Marcia congesta* Conr. (*Tellina congesta* Conr.).[38]
- *Nucula townsendi* Dall (ranges into Astoria).
- *Pecten peckhami* Gabb (ranges into Tejon).
- *Venericardia montereyana* Arn.[38]

GASTEROPODA:
- *Caesia arnoldi* F. M. And. (ranges into Empire).
- *Ficus kernianus* Cooper.[38]
- *Polinices saxea* Conr.[38]
- *Turritella cf. variata* Conr.[38]

This unmistakably fixes the identity of the *Agasoma* zone of California and what the senior writer[40] has described from the north coast of Washington as the Clallam formation with the Monterey shale, and it is proposed to unite all these under this prior name. It should be specifically understood however that another formation in California, the Lower Vaqueros, *i. e.,* the zone of the beds in the Las Vaqueros Valley, to which the name Vaqueros was applied by Hamlin[41] and from which were obtained such species as *Mytilus expansus* Arn., *Ostrea* cf. *Tayloriana* Gabb, *Ostrea* cf. *Titan* Conr., *Pecten magnolia* Conr., and *Turritella inezana* Conr., are not included in the Monterey. This formation lies unconformably below the Monterey in the Santa Monica Mountains, in the Santa Clara River Valley (where it is more particularly characterized by *Scutella fairbanksi* Arn.), and in the Santa Cruz Mountains. For it the name Vaqueros is retained.

Perhaps the only objection to the use of the term "Monterey Formation," and certainly not an important one from a palæonto-

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[38] Species characteristic of this horizon.

[39] Species still living.

[40] *Bull. Geol. Soc. Am.,* XVIII., 1906, p. 461.

[41] Water Supply Paper 89, U. S. Geol. Sur., 1904, p. 14.

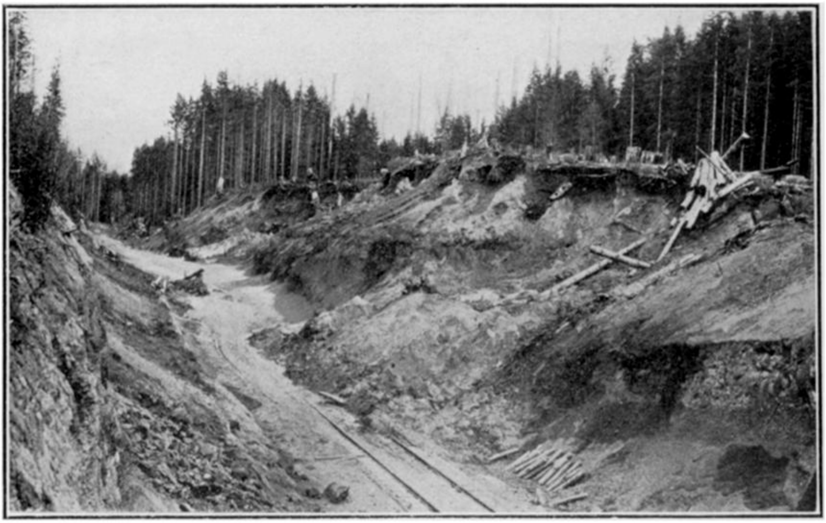

FIG. A.

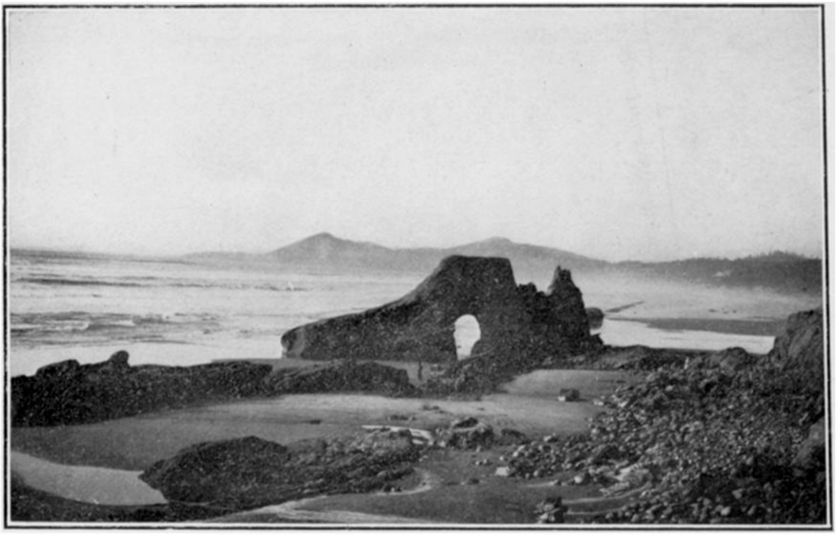

FIG. B.

FIG. A. Landsliding in soft clayshales of Monterey formation on O. W. Milwaukee Railway between Cosmopolis and North River, Washington.

FIG. B. Jump-off-Joe rock and Cape Foulweather light-house, Newport, Oregon. The rocks in the foreground are Monterey sandstones and shales, in the distance basalts intruded in the Monterey.

logical standpoint, is total absence on the North Pacific Coast of any beds in this formation, or in any other formation for that matter, lithologically similar to the diatomaceous shales so prevalent in Monterey of California. This became vital, however, from the point of view of the economic geologist since upon the presence of such shales or similar organic deposits equally lacking here, depends the possibilities of the discovery of petroleum in commercial quantities. Except for coal near Clallam Bay, Washington,[42] and on the North Nehalem River in Oregon[43] no organic products of economic value are known in this formation.

The Monterey formation of this region ordinarily consists of two members; the lower a massive buff sandstone often containing thin lignite seams and attaining south of the Chehalis River a thickness of perhaps 1,500 feet; the upper fine soft clay shales perhaps 2,500 feet thick in the same section which is one of the most complete.

To this formation are referred the conglomerates overlying the San Lorenzo shales at Carmanah Point on Vancouver Island; and in Washington: the Clallam section and the conglomerates unconformable on the Seattle beds between West Clallam and the Hoko River; a small area of Tertiary sandstone faulted into the so-called Cretaceous north of the Hoh River; an area of shales faulted against the Empire formation on the upper Wishkah River; the westward dipping monoclinal section from a few miles west of Elma to North River Junction on the south side of the Chehalis River and equivalent strata south to the Willipa River; and an isolated area beneath the Pliocene basalt on Elocheman River about twelve miles above the Columbia. In Oregon isolated areas lying on the Astoria series or exposed beneath the Pliocene basalt at Mountain Dale, Westport, the foot of 19th Street at Astoria, and the south shore of Tillamook Harbor are of this age as well as a narrow belt of rocks faulted against the Astoria series and extending for several miles up and down the coast west of Newport.

The following species were obtained in the Clallam section and at Astoria.

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[42] R. Arnold, Bull. 260, U. S. Geol. Sur., 1905, p. 413–427.

[43] J. S. Diller, 17th Ann. Rept. U. S. Geol. Sur., Pt. I., 1896, p. 494.

Partial List of Species in the Monterey Formation (Oligocene-Miocene) of the Clallam Bay District, Washington, and at Astoria, Oregon.

	45	89	160	161	162	163
PELECYPODA:						
Acila conradi Meek	×	×	...	...	...	×
Arca devincta Conr. (*A. montereyana* Osmont)[44]	×	×	×	×	×	×
Arca trilineata Conr	...	×	...	...	...	...
Diplodonta parilis Conr	×	...	...	...	...	...
Dosinia whitneyi Gabb[44]	...	...	×	×	...	...
Leda penita Conr.[44]	×	×	...	...	...	...
Macoma piercei Arn.[44]	...	...	...	×	...	...
Marcia oregonensis Conr. (*M. subdiaphana* Cpr.)[45]	×	×	...	×	...	×
Modiolus rectus Conr. (*M. directus* Dall)[45]	×	...	...	×	...	...
Panope generosa Gld.[45]	×	×	...	×	...	×
Pecten fucanus Dall[44]	...	×	...	×	...	×
Pecten propatulus Conr.[44]	×	×	×	...	...	...
Phacoides acutilineatus Conr	×	...	...	×	...	×
Solen curtus Conr	×	×	...	×	...	...
Spisula albaria Conr	×	×	...	×	...	×
Spisula catilliformis Conr.[45]	...	×	...	...	...	...
Tellina arctata Conr.[44]	×	×	...	×	...	×
Tellina nuculana Dall[44]	×	...	...	...	...	...
Tellina obruta Conr. (*T. albaria* Conr.)	×	...	...	×	...	×
Tellina oregonensis Conr	×	×	...	...	...	×
Thracia trapezoidea Conr	×	×	...	×	...	×
Thyasira bisecta Conr.[45]	×	...	...	×	...	...
Venericardia subtenta Conr. (*V. quadrata* Dall)[44]	...	...	...	×	...	×
Venus clallamensis Rgn. (*V. ensifera* Dall)[44]	×	×	...	×	...	...
Venus olympidea Rgn.[44]	...	×	...	...	...	...
Yoldia impressa Conr	×	...	...	...	...	...
Yoldia oregona Shum	×	...	...	...	...	...
GASTEROPODA:						
Ampullina oregonensis Dall	×	...	...	...	...	...
Cæsia arnoldi F. M. And.	×	...	...	×	...	...
Chrysodomus nodiferus Conr. (*Fusus stanfordensis* Arn.)	×	×	...	×	...	...
Crepidula prœrupta Conr	×	×	...	×	...	...
Cylichnella petrosa Conr.[44]	×	...	...	...	...	...
Ficus stanfordensis Arn	...	×	...	...	...	...
Fusinus corpulentus Conr. (*F. medialis* Conr.)[44]	×	...	...	...	...	...
Fusinus devinctus Conr.[44]	×	...	...	...	...	...
Natica oregonensis Conr	×	...	...	×	...	...
Polinices saxea Conr.[44]	...	×	...	×	...	...
Priscofusus geniculus Conr.[44]	×	...	...	×	...	×
Sinum scopulosum Conr	×	×	...	...	...	...
Turris wynoocheensis Wvr.[44]	...	...	...	...	...	×
Turritella oregonensis Conr.[44]	×	...	...	...	...	...
SCAPHOPODA:						
Dentalium conradi Dall (*D. petricola* Dall)	×	×	...	×	...	×
CEPHALOPODA:						
Aturia angustata Conr	...	...	...	...	...	×

Locality 45; basal sandstone, beach at foot of 19th Street, Astoria, Oregon. (H. Hannibal.)

[44] Species characteristic of this horizon.

[45] Species still living.

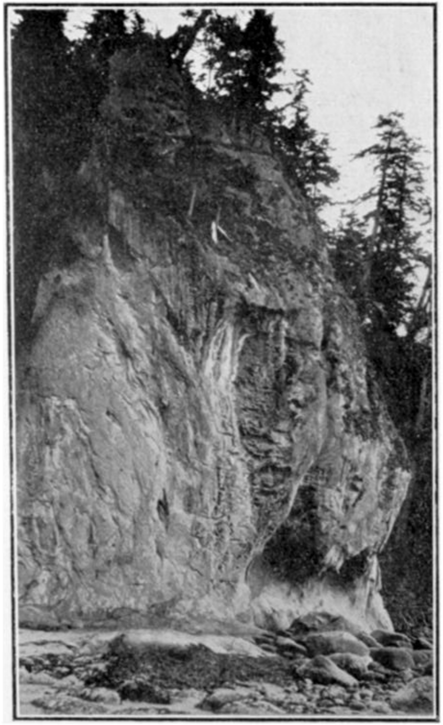

FIG. A.

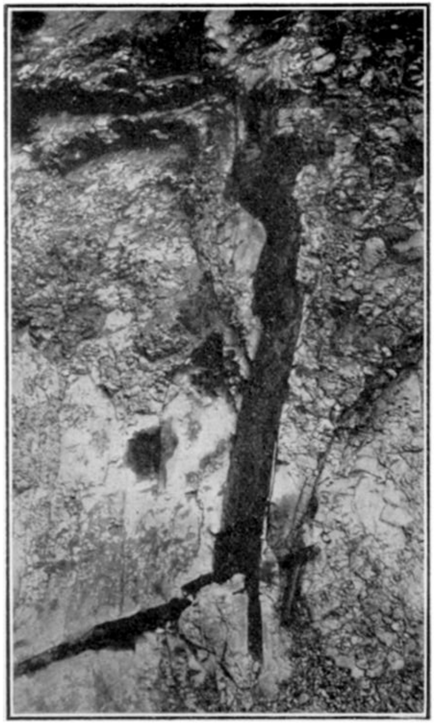

FIG. B.

FIG. A. Monterey sandstone at Pillar Point near Clallam Bay, Washington.
FIG. B. Sandstone dyke in tuffaceous Empire shales on upper reaches of Wishkah River, Aberdeen, Washington.

Locality 89; basal sandstone and conglomerate, seacliffs eastward from Slip Point for half a mile along shore, Clallam Bay, Washington. (A. B. Reagan, H. Hannibal.)

Locality 160; massive sandstone, seacliffs at Pillar Point near Clallam Bay, Washington. (H. Hannibal.)

Locality 161; shaly sandstone, seacliffs one and one half miles west of Pillar Point near Clallam Bay, Washington. (H. Hannibal.)

Locality 162; carbonaceous sandstone, seacliffs at Clallam coal mine near Clallam Bay, Washington. (H. Hannibal.)

Locality 163; shaly sandstone, seacliffs one and one half miles west of Clallam coal mine near Clallam Bay, Washington. (H. Hannibal.)

The Empire Formation (Miocene).

To beds exposed on the east shore of Coos Bay south of Empire, Oregon, Diller[46] has given the name Empire formation. This horizon the junior writer found in his field work to be widespread in Western Oregon and Washington. In many respects the Empire fauna is peculiar since it evidently represents the oldest distinctly Miocene strata on the Pacific Coast. For, while the fauna is perhaps most closely allied to the *Scutella breweriana-S. gabbi* beds of the San Pablo formation of the San Francisco Bay region in California, the larger proportion of recent species in those deposits and rather marked faunal differences preclude an exact correlation.

In the Empire district about 500 feet of beds, sandstones at the base grading upward into massive shales partially organic in character, but more or less derived from worked over volcanic debris, represent the formation. At Cape Blanco sandstones alternating with compact bedded volcanic ash containing abundant plant remains attain about the same thickness. In the area between Willipa Harbor and Grays Harbor in Washington the base of the formation is represented, being marked by a zone of basalt tuffs and breccias. The most important area, however, lies between the Chehalis Valley and the foot of the Olympic Mountains, where the formation attains a thickness of perhaps 4,000 feet, chiefly sandstones at the base grading upward into massive tuffaceous shales with some intercalated sandstones. Small Empire areas occur on the west coast of the Olympic Peninsula between Cape Grenville and

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[46] 17th Ann. Rept. U. S. Geol. Sur., Pt. I., 1896, p. 475.

Partial List of Species in the Empire Formation (Middle Miocene) of the Coos Bay-Cape Blanco District, Southwestern Oregon.

	23	26	31	36	37	39	43	44
PELECYPODA:								
Acila conradi Meek	...	X	...	...	X	...	...	...
Arca trilineata Conr	...	X	...	...	X	...	...	...
Cardium coosense Dall[48]	...	...	...	X	...	...	...	...
Cardium meekianum Gabb	...	X	...	X	X	...	...	...
Diplodonta parilis Conr	...	X	...	...	X	...	...	...
Glycymeris grewingki Dall[48] (*G. gabbi* Dall, *G. conradi* Dall)	...	X	...	...	X	...	...	X
Macoma astori Dall[48]	...	...	...	...	X	...	...	X
Macoma calcarea Gmel.[49]	...	X	...	X	...	...	X	...
Macoma inquinata Desh.[49]	...	...	...	...	...	...	X	...
Marcia oregonensis Conr. (*M. subdiaphana* Cpr.)[49]	...	X	...	X	...	...	X	X
Modiolus rectus Conr. (*M. directus* Dall)[49]	...	...	...	...	X	...	...	...
Mulinia densata Conr. (*M. oregonensis* Dall)	...	...	...	...	X	...	...	...
Mya truncata L.[49]	...	...	...	X	...	...	...	...
Mytilus middendorffi Grnk. (*M. condoni* Dall)[48]	X	X	...	...	...	...	...	...
Panomya ampla Dall (*P. chrysis* Dall)[49]	...	...	...	...	...	...	X	...
Parapholas californica Conr.[49]	...	...	...	...	...	...	X	...
Paphia stayleyi Gabb	...	...	...	X	...	...	X	...
Pecten coosensis Shum[48]	...	...	...	X	...	X	...	...
Phacoides acutilineatus Conr	...	...	...	...	X	...	...	...
Schizothærus pajaroanus Conr	...	...	...	...	X	...	...	...
Siliqua nuttalli Conr. (*S. oregonia* Dall)[49]	...	X	...	...	...	...	...	...
Solen sicarius Gld. (*S. conradi* Dall)[49]	...	X	...	X	X	...	X	X
Spisula albaria Conr. (*S. præcursor* Dall)	...	X	...	X	X	X	X	X
Tellina aragonia Dall[48]	...	X	...	...	X	...	...	...
Thracia trapezoidea Conr	...	...	...	X	...	...	...	...
Venus securis Shum. (*V. parapodema* Dall)	...	X	...	...	X	...	...	...
Yoldia impressa Conr	...	...	...	X	...	...	...	...
Yoldia oregona Shum	...	...	...	...	X	...	...	...
Yoldia strigata Dall	...	...	...	X	...	...	...	...
GASTEROPODA:								
Ampullina oregonensis Dall	...	...	...	X	...	...	...	...
Argobuccinum cammani Dall[48]	...	...	...	X	...	...	...	X
Argobuccinum coosense Dall[48]	...	...	...	...	...	...	X	...
Bathytoma gabbiana Dall[48]	...	...	...	X	...	...	...	...
Boreotrophon stuarti Smith[49]	...	...	...	X	...	...	X	...
Bullia bogachielia Rgn.[48]	...	X	...	...	...	...	...	...
Cæsia arnoldi F. M. And.	...	X	...	...	X	...	...	...
Calliostoma cammani Dall[48]	...	...	...	X	...	...	...	...
Calyptræa inornata Gabb	...	...	...	X	X	...	...	...
Cancellaria oregonensis Dall[48]	...	X	...	...	...	...	...	...
Chrysodomus bairdi Dall[48]	...	...	...	X	...	...	...	...
Chrysodomus imperialis Dall	...	...	...	X	...	...	...	...
Chrysodomus nodiferus Conr. (*Fusus stanfordensis* Arn.)	...	X	...	...	...	...	...	...
Crepidula adunca Sby.[49]	...	X	...	...	...	...	...	...
Crepidula princeps Conr	...	...	...	...	X	...	...	X
Cymatium pacificum Dall[48]	...	X	...	X	...	...	...	...
Fusinus coosensis Dall[48]	...	X	...	X	...	...	...	X
Miopleionia oregonensis Dall	...	...	...	...	X	...	...	X
Natica clausa B. & S. (*N. consors* Dall)[49]	X	X	...	X	X	...	X	X

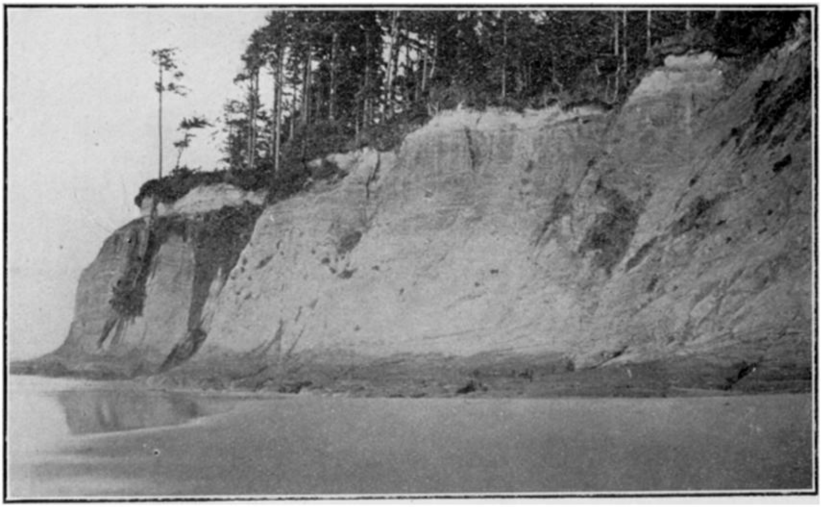

FIG. A.

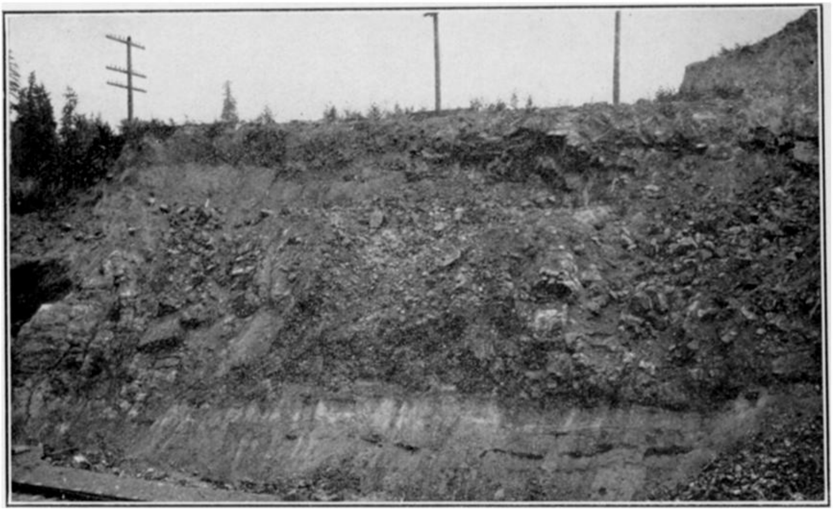

FIG. B.

FIG. A. West face of Coos Head, Coos Bay, Oregon. Empire sandstone overlain by Pleistocene sands.

FIG. B. Pliocene basalts associated with river sands and gravel on Portland-Tacoma Railway below Little Falls, Washington.

	23	26	31	36	37	39	43	44
GASTEROPODA:								
Nucella decemcostata Midd. (*Thais præcursor* Dall)[49]	×	×	...	×	...	...	...	×
Nucella lamellosa Gmel. (*Purpura crispata* Chem.)[49]	...	...	...	...	...	...	...	×
Olivella biplicata Sby.[49]	...	×	...	...	...	...	...	...
Olivella pedroana Conr.[49]	...	...	...	×	...	...	...	...
Phalium æquisulcatum Dall[48]	...	...	...	×	...	...	...	...
Phalium turricula Dall[48]	...	...	...	×	...	...	...	...
Polinices galianoi Dall	...	...	...	×	...	...	...	...
Tegula stantoni Dall[48]	...	...	...	×	...	...	...	...
Turris coli Dall[48]	...	...	...	...	...	...	×	...
Turris impecunia Dall[48]	...	×	...	×	...	...	...	...
Turris perversa Gabb[49]	...	...	...	×	...	...	...	...
Sinum scopulosum Conr	...	...	...	...	...	...	...	×
SCAPHOPODA:								
Dentalium rectius Cpr.[49]	...	...	...	×	...	...	...	...
BRACHIOPODA:								
Discinisca oregonensis Dall	...	...	...	...	...	...	×	...
Terebratalia occidentalis Dall[49]	...	...	...	...	...	...	×	...
ECHINODERMATA:								
Scutella gabbi Rem.[48]	...	×	...	...	×	...	...	...
PISCES:								
Isurus planus Ag.	...	...	×	...	...	...	...	...

Locality 23; basal sandstone, seacliffs between Blacklock Point and Floras Lake, Cape Blanco, Oregon. (H. Hannibal.)

Locality 26; basal sandstone, seacliffs southeast of lighthouse for a mile along shore, Cape Blanco, Oregon. (F. F. Wood, H. Hannibal.)

Locality 31; massive shale, beach one fourth of a mile north of South Slough bridge, east shore of Coos Bay, Oregon. (H. Hannibal.)

Locality 36; shaly sandstone, beach between submerged jetty and Fossil Rock, three miles south of Empire, Coos Bay, Oregon. (H. Hannibal.)

Locality 37; basal sandstone, beach for a mile toward Empire from Tarheel Point, Coos Bay, Oregon. (H. Hannibal.)

Locality 39; shaly sandstone, north face of Coos Head, Coos Bay, Oregon. (H. Hannibal.)

Locality 43; basal sandstone, seacliffs between Astoria-Empire unconformity and Goldwashers Gully, coast west of Coos Bay, Oregon. (H. Hannibal.)

Locality 44; basal sandstone, seacliffs between Goldwashers Gully and Coos Head, coast west of Coos Bay, Oregon. (H. Hannibal.)

the mouth of the Quinaielt River, between Cape Elizabeth and Raft River, at the mouth of Raft River, and on the Bogochiel River above

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[48] Species characteristic of this horizon.

[49] Species still living.

Mora. The Tertiary rocks of Tchow-un Point,[49a] Queen Charlotte Islands, represent the same horizon.

The following fauna was obtained at Cape Blanco and Coos Bay, Oregon.

THE MERCED FORMATION (MIOCENE-PLIOCENE).

In terming the latest Miocene or earliest Pliocene deposits of the North Pacific Coast the Merced Formation, the writers recognize the contemporaneity of the Scotia section of Eel River Valley, California, the Coos Conglomerate of Coos Bay, Oregon, and the Miocene-Pliocene portion of the Quinaielt formation near Taholah, Washington, with the Miocene-Pliocene beds of the Seven-mile section and exposures on Twelve-mile Creek south of San Francisco, California.

As originally constituted by Lawson[50] the Merced formation apparently included two members, the one in question, steeply tilting beds extending in the Seven-mile Beach section from Mussel Rock northward to the highest *Scutella* bed, the other nearly horizontal sands and clays west of Colma containing a small fauna composed entirely of living species. Subsequently Ashley[51] utilized the name Merced for the older portion, pointing out that the upper beds should be considered separately. Recent collections made by the junior writer show conclusively that the upper horizontal beds are Quaternary and, though the contact is obscure, water-worn pebbles containing *Scutella interlinerta* Stimp. present in them indicate an unconformity with the underlying Miocene-Pliocene.

Partial List of Species in the Merced Formation (Miocene-Pliocene) of the San Francisco Peninsula and Eel River Valley, California.

PELECYPODA:

Arca trilineata Conr., *S.*
Cardium meekianum Gabb, *S, E.*
Diplodonta orbella Gld., *S.*[52]
Glycymeris coalingensis Arn., *E.*[53]
Macoma calcarea Gmel., *E.*[52]

[49a] Dawson, G. M., Rept. Geol. Sur. Can., 1788–9 (1880), p. 87*B*, calls this Skonum Point. Dr. C. F. Newcombe informs the writer that Tchow-un is more correct.

[50] Bull. Dept. Geol. Univ. Cal., I., 1894, p. 115–160.

[51] *Jour. Geol.*, III., 1895, p. 441–6.

Macoma nasuta Conr., *S*.[52]
Marcia oregonensis Conr. (*M. subdiaphana* Cpr.), *S, E*.[52]
Mulinia densata Conr., *S, E.*
Panomya ampla Dall (*P. chrysis* Dall), *E*.[52]
Paphia staleyi Gabb, *S, E.*
Paphia tenerrima Conr., *S*.[52]
Pecten caurinus Gld., *S, E*.[52]
Pecten dilleri Dall, *E*.[53]
Pecten healeyi Arn., *S*.[53]
Pecten nutteri Arn., *S.*
Psephidia lordi Baird, *S, E*.[52]
Schizothaerus nuttalli Conr., *S*.[52]
Schizothaerus pajaroanus Conr., *E.*
Siliqua nuttalli Conr., *S, E*.[52]
Solen sicarius Gld., *S*.[52]
Spisula voyi Gabb (*S. alaskana* Dall), *S, E*.[52]
Tellina buttoni Dall, *S*.[52]
Thracia trapezoidea Conr., *E.*
Venus securis Shum., *S.*

GASTEROPODA:
Caesia mendica Gld., *S*.[52]
Chrysodomus stantoni Arn., *S*.[53]
Chrysodomus tabulatus Baird, *S, E*.[52]
Columbella gausapata Gld. (*Astyris richthofeni* Gabb), *S, E*.[53]
Crepidula onyx Sby., *S*.[52]
Crepidula princeps Conr., *S.*
Natica clausa B. & S., *S, E*.[52]
Nucella decemcostata Midd. (*Purpura lima* auct.), *S*.[53]
Nucella lamellosa Gmel., *S, E*.[53]
Nucella saxicola Val., *S*.[52]
Olivella biplicata Sby., *S*.[52]
Polinices galianoi Dall, *S.*
Stylidium eschrichti Midd. (*Bittium filosum* Gld.), *S*.[53]

SCAPHOPODA:
Dentalium rectius Cpr., *E*.[52]

ECHINODERMATA:
Echinarachnius gibbsi Rem., *S*.[53]
Scutella interlineata Stimp., *S*.[53]
Scutella oregonensis Clark, *S, E.*

S—San Francisco Peninsula. *E*—Eel River Valley.

NOTE.—This and succeeding lists from the Merced and Elk River formations should not be used as a basis for determining percentages of species living or extinct. It has not been convenient to identify all the living species in time to include them on the lists, and in addition a number of undescribed extinct forms occur.

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[52] Species still living.

[53] Species characteristic of this horizon.

The Merced areas on the North Pacific Coast are, without exception, small and isolated. Deposits limited to the basal conglomerates attain in Oregon a thickness of a few feet at two points on the east shore of Coos Bay south of Empire, and again at the point south of Five-mile Creek on the coast near Bandon.

Partial List of Species in the Merced Formation (Miocene-Pliocene) of the Coast of Oregon and Washington.

	Oregon			Washington		
	34	35	98	77	79	80
PELECYPODA:						
Cardium meekianum Gabb	...	...	...	×	...	...
Macoma calcarea Gmel.[54]	...	...	...	×	...	...
Macoma nasuta Conr.	×	...	...	...	...	...
Marcia oregonensis Conr. (*M. subdiaphana* Cpr.)[54]	...	...	...	×	...	...
Mulinia densata Conr. (*M. oregonensis* Dall)	×	...	...	...	...	...
Mytilus edulis L.[54]	...	...	...	...	...	×
Ostrea cf. lurida Cpr.[54]	...	...	×	...	...	...
Panope generosa Conr.[54]	...	...	...	...	...	×
Pecten caurinus Gld.[54]	×	...	...	...	...	...
Pecten dilleri Dall[55]	...	...	...	...	×	...
Phacoides annulatus Rve.[54]	...	...	...	×	...	...
Pholadidea penita Conr.[54]	×	...	...	...	...	...
Psephidia lordi Bd.[54]	...	...	×	...	...	...
Solen sicarius Gld.[54]	...	...	...	×	...	...
Spisula albaria Conr.	...	...	...	×	...	×
Spisula voyi Gabb (*S. alaskana* Dall)[54]	...	...	×	...	...	...
Thyasira bisecta Conr.[54]	...	...	...	...	×	...
Venus securis Shum.	...	...	...	×	...	...
GASTEROPODA:						
Argobuccinum oregonense Redf.[54]	×	...	...	...	...	...
Astræa inequalis Mart.[54]	×	...	...	...	...	...
Cæsia mendica Gld.[54]	...	...	...	×	...	...
Chrysodomus imperialis Dall.	×	...	...	×	...	...
Chrysodomus tabulatus Bd.[54]	...	×	...	...	...	...
Gyrineum marshalli Rgn. (*G. mediocre* Dall)	...	...	...	×	...	...
Littorina remondi Gabb (*L. petricola* Dall)	×	×	...	...	...	...
Natica clausa B. & S.[54]	...	...	...	×	×	...
Nucella decemcostata Midd.[54]	...	×	...	×	...	...
Olivella pedroana Conr.[54]	×	×	...	...	...	...
Purpura foliata Mart.[54]	×	...	...	...	...	...
Stylidium eschrichti Midd. (*Bittium filosum* Gld.)[54]	×	...	...	...	...	...
Tritonalia lurida Midd.[54]	...	...	...	×	...	...
Turcica caffea Gabb[54]	...	...	...	×	...	...
Turris perversa Gabb[54]	...	×	...	×	...	...

Locality 34; basal conglomerate and sandstone, Fossil Rock, three and one half miles south of Empire, Coos Bay, Oregon. (H. Hannibal.)

---

[54] Species still living.

[55] Species characteristic of this horizon.

Locality 35; basal conglomerate, point south of Fossil Rock, four miles south of Empire, Coos Bay, Oregon. (H. Hannibal.)

Locality 98; basal conglomerate, seacliffs at point three fourths of a mile south of Five Mile Creek, Bandon, Oregon. (H. Hannibal.)

Locality 77; sandstone, seacliffs from Cape Grenville northward for a mile to long landslide, Taholah, Washington. (H. Hannibal.)

Locality 79; shaly sandstone, seacliffs north of Quinaielt River bar, Taholah, Washington. (H. Hannibal.)

Locality 80; sandstone, seacliffs from Cape Elizabeth northward for three fourths of a mile to big landslide, Taholah, Washington. (H. Hannibal.)

Two areas of soft semicoherent sandstone faulted into the Older Tertiary and Mesozoic rocks on the coast of the Olympic Peninsula near Taholah, Washington, contain a fauna evidently the same age. The thickness here is perhaps 500 feet.

THE ELK RIVER FORMATION (UPPER PLIOCENE).

Extending from the Goldwashers' cabin one and three fourths miles southeast of Cape Blanco south to Garrison Lagoon near Port Orford, Oregon, is a gently southward dipping cliff, essentially a raised beach composed of sands and littoral gravels, blue and more or less concretionized at the base but rusty and hardly consolidated above, perhaps 250 feet thick near their contact with the Empire sandstone lying to the north but gradually dropping down below sea level to the south. This formation has been named by Diller[56] the Elk River beds from an important stream which cuts through the section. As a matter of fact Diller's name was given only to the upper rusty portion of the section while the blue beds conformable below were included with the Empire (Cape Blaco Beds) a procedure not borne out by the character of the fauna. It might be added that there is a marked discrepancy between the dip and strike of the Empire beds and the overlying blue sands where the two formations meet that was apparently overlooked by Diller.

The fauna of the Elk River beds consists chiefly of recent species but associated with them are others common to the Merced, thus establishing the Pliocene age of the formation. In a general way this fauna suggests the Deadman Island or Santa Barbara Pliocene in the boreal facies of the fauna and the small percentage of extinct forms, though the two formations have only one characteristic species, *Turris smithi* Arn., in common.

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[56] Bull. 196, U. S. Geol. Sur., 1902, p. 31.

Partial List of Species in the Elk River Formation (Upper Pliocene) at the Seacliff North of the Mouth of Elk River, Port Orford, Oregon.

(F. F. Wood, H. Hannibal, collectors.)

PELECYPODA:

- *Cardium corbis* Mart.[57]
- *Cryptomya oregonensis* Dall.
- *Kennerlia grandis* Midd.[57]
- *Leda acuta* Conr.[57]
- *Macoma inquinata* Desh.[57]
- *Macoma nasuta* Conr.[57]
- *Modiolus modiolus* L.[57]
- *Modiolus rectus* Conr.[57]
- *Mya truncata* L.[57]
- *Mytilus californianus* Conr.[57]
- *Mytilus edulis* L.[57]
- *Paphia staminea* Conr.[57]
- *Pecten caurinus* Gld.[57]
- *Psephidia lordi* Baird.[57]
- *Saxidomus giganteus* Desh.[57]
- *Siliqua nuttalli* Conr.[57]
- *Spisula cf. albaria* Conr.
- *Spisula falcata* Gld.[57]
- *Spisula voyi* Gabb (*S. alaskana* Dall).[57]
- *Thracia trapezoidea* Conr.
- *Venericardia ventricosa* Gld.[57]

GASTEROPODA:

- *Amphissa corrugata* Rve. and var. *versicolor* Dall.[57]
- *Argobuccinum oregonense* Redf.[57]
- *Bela tabulata* Cpr.[57]
- *Boreotrophon gracilis* Perry.[57]
- *Boreotrophon stuarti* Baird.[57]
- *Buccinum strigillatum* Dall.[57]
- *Calliostoma costatum* Mart.[57]
- *Caesia fossata* Gld.[57]
- *Caesia perpinguis* Hds.[57]
- *Calyptraea fastigiata* Gld.[57]
- *Chrysodomus phoeniceus* Dall.[57]
- *Chrysodomus tabulatus* Baird.[57]
- *Columbella gausapata* Gld.[57]
- *Epitonium hindsii* Cpr.[57]
- *Lacuna vincta* Mtg.[57]
- *Lepeta concentrica* Midd.[57]
- *Margarites pupilla* Gld.[57]

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[57] Species still living.

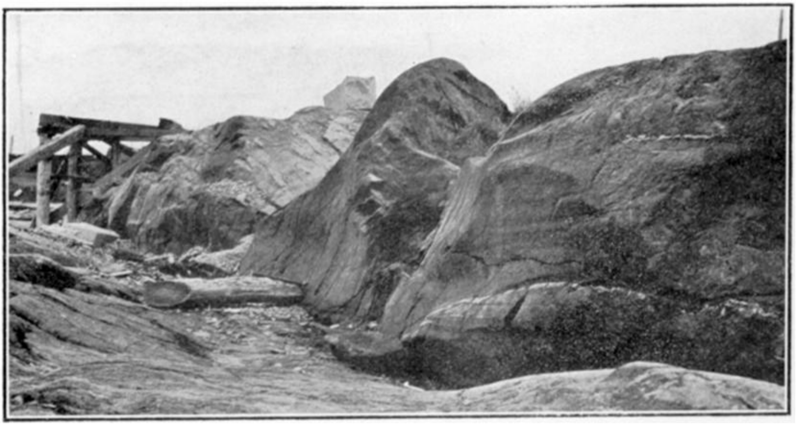

FIG. A.

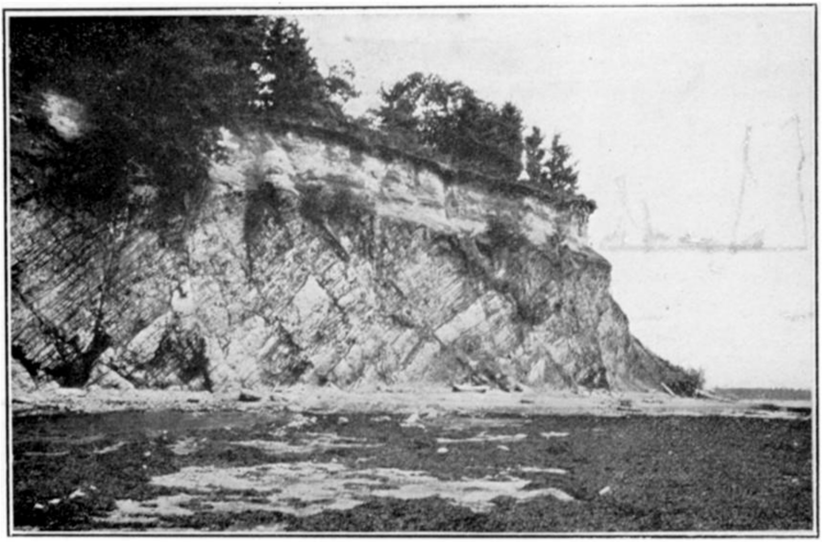

FIG. B.

FIG. A. Glacial grooving of Vancouver greenstone-diorites at entrance to Victoria Harbor, Vancouver Island.

FIG. B. Seattle shale (Astoria series) overlain by Pleistocene sands. Ilwaco. Washington.

Natica clausa B. & S.[57]
Nucella decemcostata Midd. (*Purpura lima* auct.).[57]
Nucella lamellosa Gmel. (*Purpura crispata* Chem.).[57]
Nucella saxicola Val.[57]
Olivella biplicata Sby.[57]
Olivella pedroana Conr.[57]
Polinices draconis Dall.[57]
Polinices pallida B. & S.[57]
Puncturella galeata Gld.[57]
Purpura foliata Gmel.[57]
Sipho halibrectus Dall.[57]
Solariella cidaris A. Ad.[57]
Trichotropis cancellata Hds.[57]
Tritonalia lurida Midd.[57]
Tritonifusus rectirostis Dall.[57]
Turris perversa Gabb.[57]
Turris smithi Arn.
BRACHIOPODA:
Hemithyris psittacea L.
ECHINODERMATA:
Scutella oregonensis Clark.

THE SAANICH FORMATION (PLEISTOCENE).

Benching the Oligocene and glacial deposits at Alki Point and Bainbridge Island in Puget Sound, filling glacial depressions at various points north of Victoria on the Saanich Peninsula of Vancouver Island, and terracing the length and breadth of the Straits of Georgia notably the Sucia Islands is a raised beach deposit for which the writers propose the name Saanich Formation. This formation carries numerous mollusca, usually species now living in adjacent waters, but others extinct or like *Pecten islandicus* Müller, *Cardium decoratum* Grnk. and *Mya arenaria* L. are now native only off the Alaska coast or at other arctic points. In this respect it resembles the lower San Pedro fauna which contains species now confined several hundred miles or more northward.

Overlying the marine deposits in several glacial hollows on the Saanich Peninsula are peat and marl beds containing numerous freshwater shells, the species being identical with those found in adjacent lakes. It appears that after the Post-Saanich elevation these hollows were filled by freshwater lakes and gradually silted up as Swan Lake and others on the Saanich peninsula are yet doing.

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[57] Species still living.

With the Saanich formation are tentatively included the widespread raised beaches on the west coast of Oregon and Washington containing marine shells at Cape Blanco, Bandon, and Newport in the former state and at Bay Center in the latter. Reagan[58] mentions the occurrence of marine shells in Pleistocene deposits at Beaver Prairie on the Olympic Peninsula, but the locality here is an old kitchenmidden.

Partial List of Species in the Saanich Formation (Pleistocene) of Puget Sound and the Straits of Georgia.

PELECYPODA:
- *Cardium corbis* Mart.
- *Cardium decoratum* Grnk.[59]
- *Macoma calcarea* Gmel.
- *Macoma inquinata* Desh.
- *Macoma nasuta* Conr.
- *Mya arenaria* L.[59]
- *Mya truncata* L.
- *Mytilus edulis* L.
- *Paphia staminea* Conr.
- *Paphia tenerrima* Conr.
- *Pecten islandicus* Müll.[59]
- *Pecten hastatus hericeus* Gld.
- *Saxicava arctica* L.
- *Saxidomus giganteus* Desh.
- *Serripes groenlandicus* Gmel.
- *Schizothaerus nuttalli* Conr.

GASTEROPODA:
- *Buccinum percrassum* Dall.
- *Natica clausa* B. & S.
- *Nucella lamellosa* Gmel.
- *Polinices lewisii* Gld.

GEOLOGICAL HISTORY.

The Coast Range of Oregon and the Willamette Valley.

The Coast Range, Willamette Valley, and Cascade Range of Oregon as has been intimated in the discussion of the Arago lavas were apparently built up during Eocene time as a gently westward

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[58] Geological Papers Kans. Acad. Sci., 1908, p. 229.

[59] Species now native only to northward.

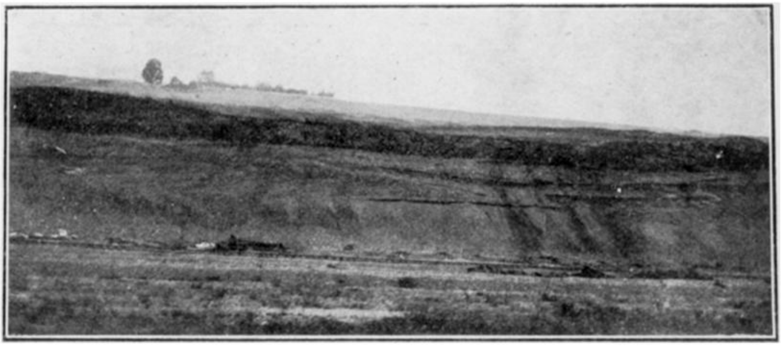

FIG. A.

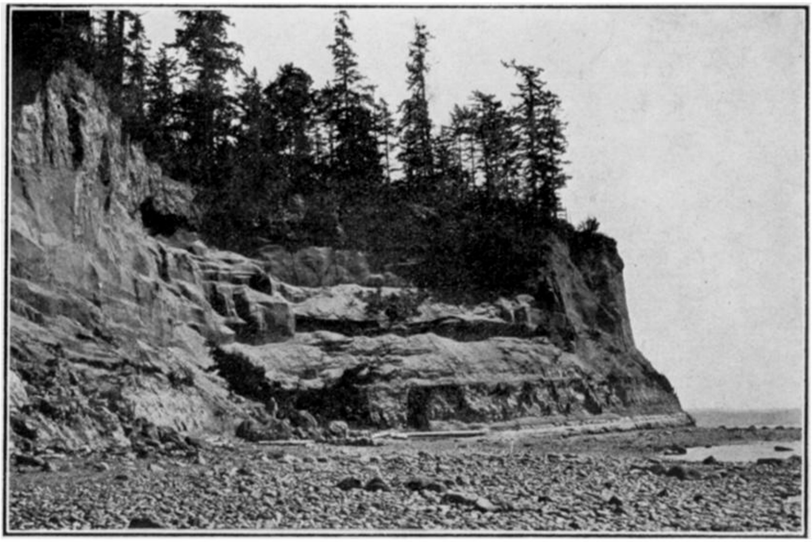

FIG. B.

FIG. A. Steilacoom gravels (outwash of Vashon drift), prairie between Gate and Olympia, Washington.

FIG. B. Glacial deposits at south end of Marrowstone Island, Port Townsend, Washington.

sloping floor of successive basaltic flows and tuffs. In the Cascade Mountains intercalated sediments are reduced to a minimum but farther to the west and south they apparently replace more and more the igneous materials. With the close of the Tejon this floor was elevated into the form of a plateau with a synclinal sag at the present position of the Willamette Valley. At the opening of the Astoria period of sedimentation an arm of the sea extending up the Willamette Valley at least as far as Eugene connecting across the Range at Wren and Blodgett but it was not until the Seattle Epoch that the Coast Range was completely submerged by the load of igneous and sedimentary detritus piled upon it, for at many points on the west flank particularly near Nehalem and Tillomook Harbors the Seattle beds rest directly on the Eocene with the lower Astoria (San Lorenzo) lacking. Following this, western Oregon was elevated and except for an embayment of the Monterey sea which extended up the Columbia River and southward to the Tualatin Valley west of Portland, no later sediments have been deposited inland from the extreme western border. It is probable that the coast line has stood near its present position during much of late Tertiary time owing to the existence of an important fault paralleling the coast for many miles. Elevations on the east side of this fault have resulted in the removal of all the later and much of the early Tertiary deposits and submergences on the west side have carried the successive deposits even deeper beneath the sea.

Much has been written of the continuity of the Willamette Valley with the geosynclinal trough of the Great Valley of California, but facts do not bear this out. The Willamette Valley is the result of the differential erosion of soft shales and sandstones compared with the basalts which flank it. It is underlain at no great depth by Eocene deposits, igneous and sedimentary, which frequently stand up as monadnocks through the thin veneer of fluvial deposits and alluvium. The so-called "Willamette Sound" either refers to the Oligocene embayment or to the fluvial deposits in the Willamette Valley above Oregon City where a late Tertiary basalt flow impinged in passing down the lower Willamette and Columbia Rivers and temporarily dammed back the Willamette River.

The Chehalis Valley and Southwestern Washington.

The geologic history of this district during the Tertiary has been: *first* the deposition of the Tejon series chiefly as an estuarine deposit but with some associated lavas, mostly basalts; *second* the deformation of Tejon by folding in a west-east or northwest-southeast direction; *third* the successive deposition of the Astoria Series, and the Monterey, Empire, and Merced formations; *fourth* the final elevation of the Olympic and Cascade Mountains in Pliocene time and the resultant faulting, prevailingly in an east-west or north-south direction, of all the Tertiaries of southwestern Washington into a jumble of westward-dipping monoclinal blocks. Except locally in the proximity of faults, folding of the Oligocene and later strata of Washington is almost unknown.

The Tertiaries of the Periphery of the Olympic Complex.

The succession of events about the periphery of the Olympic complex is similar to that of southwestern Washington, except that the Tejon is very largely absent and the folding which succeeded it has left no record. On the west coast several isolated areas of Tertiary rocks have been faulted down into the Cretaceous, and thus preserved. A fault which requires special mention in this connection is the one which marks the north boundary of the Olympic Mountains, extending from the mouth of the Soo-es River south of Cape Flattery to Lake Crescent and the head of S'quim Bay an unbroken distance of more than eighty miles. On the south side except at the terminii all the adjacent rocks are pre-Tertiary. To the north lies the great monocline of northwestward-dipping Oligocene beds. It is probable that a second fault paralleling this lies in the trough of the Straits of Fuca else it is difficult to explain that remarkable topographic feature. The structure of the gently seaward-dipping Tertiary rocks of the southwest coast of Vancouver Island may also be readily explained by an assumption that such a fault exists.

Puget Sound is probably a pre-Pleistocene valley of erosion filled by glacial debris. It has been regarded as a structural depression, but if this is true it is difficult to explain why all the Tertiary and older rocks exposed about its borders or at various points in it form an integral part of a series of northward- or southward-dipping fault blocks which cross its major direction at right angles.

Notes on the Geological Formation Names Applied to the Tertiary of the North Pacific Coast.

During his work in 1911 and 1912 the junior writer made a special endeavor to visit as many as possible of the type-sections of the formations described on the North Pacific Coast and data are at hand to decide the age and status of practically all, as shown on the accompanying table. Those not already discussed may be noted chronologically.

Thos. Condon, in Cope, 1880, "Corrections of the Geological Map of Oregon."[60] The Astoria shales and *Solen* beds have already been considered in connection with the identity of the Astoria Series.

C. A. White, 1888, 1899, "On the Puget Group of Washington Territory"[61] and "The Mollusca of the Puget Group."[62] Broadly speaking the Puget Group is the equivalent of the Tejon Series. It was described as a freshwater deposit, but this is hardly true. While molluscan remains of any kind are generally scarce, several species described as freshwater forms are well-known marine Tejon species. Exactly how much of the Tejon is represented by the Puget is somewhat uncertain, however, and will continue to be so until the various floras are described and the species characteristic of the different portions of the Tejon become known. The Pierce County coal field where the Wilkeston section first described by White is located, represents about 14,700 feet of beds. The lowest 2,000 feet at the Fairfax and Montezuma mines evidently belong to the Chehalis formation judging by the flora. The upper 10,000 or 12,000 feet of beds (Carbonado, Wilkeston and Burnett formations) are certainly later and probably represent the Olequa. The beds on the Duwamish River near Allentown, eastward to Newcastle and

[60] *Am. Nat.*, XIV., 1880, p. 457.

[61] *Am. Jour. Sci.* (3d ser.), XXXVI., 1888, pp. 443–450.

[62] Bull. 51, U. S. Geol. Sur., 1889, pp. 49–63.

Squak Mountain, and southward to Green River, so far as palæobotanical evidence goes are of Chehalis age. Those at Bellingham appear to be younger, though more than one horizon may be represented. In any event the continued use of the name Puget is very misleading since the Upper Puget, so-called, is earliest Tejon (Chehalis), and the Lower Puget is later Tejon.

A. C. Lawson, 1894, "Note on the Chehalis Sandstone."[63] This formation redefined has already been considered as a division of the Tejon.

J. C. Merriam, 1896, "Note on Two Tertiary faunas from the Rocks of the south coast of Vancouver Island."[64] The section between Muir and Coal Creeks west of Sooke where Dr. Newcombe collected for Merriam in the early 90's, and courteously accompanied the junior writer in 1912, is recognized as the type of the Sooke formation. Dr. Merriam states that he never intended to name a Carmanah Point formation but the name has passed into the literature. The beds at this point are San Lorenzo shales overlain unconformably by Monterey conglomerate in the cliff beneath the lighthouse. Dr. Newcombe's collection came from the San Lorenzo shales, from Sooke boulders in the Monterey, and from the Monterey itself. The list should be expurged. The one quoted from Dall was derived from the San Lorenzo beds at Bonilla Point; it requires some revision.

W. H. Dall, 1898, "A Table of the North American Tertiary Horizons Correlated with One Another and with Those of Western Europe with Annotations."[65] The "foraminiferal shales . . . conformably underlying the Tunnel Point beds at Coos Bay, Oregon" contain a characteristic San Lorenzo fauna. The portion of the Tunnel Point beds adjacent to the "foraminiferal shales" represent a sandstone phase of the San Lorenzo. However, the bulk of the type section and the beds from which the fauna listed by Dall[66] came are of Empire age being separated from the main Empire syncline by faulting. An angular unconformity marked by Pholas-borings may be observed in a niche of the seacliffs which form the type-section of the Tunnel Point beds.

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[63] *Am. Geol.*, XIII., 1894, p. 436.

[64] *Bull. Dept. Geol. Univ. Cal.*, II., 1896, pp. 101–108.

[65] 18th Ann. Rept. U. S. Geol. Sur. (II), 1898, pp. 323–348.

[66] Prof. Paper 59, U. S. Geol. Sur., 1909, p. 15.

The *Aturia* bed at Astoria lies in the Seattle formation. As *Aturia angustata* ranges through the Astoria series and Monterey formation up and down the Pacific Coast, its value as an index-fossil of a single horizon is doubtful. The term "Astoria sandstone" appears to have been intended to cover Condon's *Solen* Beds at Astoria as well as the sandstones intercalated with the Astoria shales in the steep bluffs behind the town.

Mytilus beds; based on a locality at the north end of Shoalwater Bay (more properly Willipa Harbor), Washington, containing *Mytilus condoni* Dall = *M. middendorffi* Grnk. This is the Empire sandstone.

Coos Conglomerate, basal Merced conglomerate overlying the Empire beds at Coos Bay, Oregon. This is not the Coos Group of Vermont geological literature which is Palaeozoic.

J. S. Diller, 1896–1903, "A Geological Reconnaissance in Northwestern Oregon";[67] "Roseburg Folio," U. S. Geological Survey, 1898; "Coos Bay Folio," U. S. Geological Survey, 1901; "Topographic Development of the Klamath Mountains";[68] "Port Orford Folio," U. S. Geological Survey, 1903. The Arago is recognized as a division of the Tejon. Its subdivisions, the Pulaski and Coaledo, appear to be of interest chiefly to the coal geologist. The Tyee sandstone from the fauna at Basket Point on the Umpqua River is probably the same horizon as is also the Umpqua formation. The Wilbur tuff is a lithologic phase of the Arago, a type of rock not uncommon on the North Pacific Coast where fossiliferous beds rest upon basic igneous flows and tuffs.

The areas of Oakland limestone are so small that in the absence of a recognizable fauna it can only be considered as a local division. If post-Eocene in age, as supposed, these may represent isolated San Lorenzo areas similar to those flanking the Willamette Valley.

The relations of the Empire formation have already been considered. To this horizon are referred the lower 475 feet of the Cape Blanco beds. The upper 75 feet, argillaceous sands with some calcareous nodules, are unconformable on the Empire beds and form the base of the Elk River Formation, here referred to the Upper Pliocene.

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[67] 17th Ann. Rept. U. S. Geol. Sur., 1896, pp. 441–520.

[68] Bull. 196, U. S. Geol. Sur., 1902, pp. 30–31.

Willis and Smith, 1899, "Tacoma Folio," U. S. Geological Survey. Three divisions of the Lower Puget (middle and perhaps upper Tejon), the Carbonado formation, Wilkeston sandstone, and Burnett formation are named. So far no palæontological evidence has been advanced to insure their recognition beyond the limits of the Pierce County coal field.

R. Arnold, 1906, "A Geological Reconnaissance of the Olympic Peninsula."[69] The use of the Arago in place of Crescent, and Monterey in preference to Clallam has already been discussed. Other beds on the north coast of Washington mapped with the Clallam as undifferentiated Oligocene-Miocene are now assigned to one horizon or another of the Astoria series.

The Quinaielt formation is divided on palæontological grounds between the Empire and Merced formations.

A. B. Reagan, 1908, "Some Notes on the Olympic Peninsula."[70] Most of geological data in this paper are adopted from the one by the senior writer just mentioned. The Hoko River Pliocene, so-called, is an area of Monterey sandstone and conglomerate uncomformable on the Astoria series. The Raft River Pliocene contains a small but characteristic Empire fauna. The description of the Quillayute formation is based on the glacial filling of the valley of the Quillayute River. If Reagan had visited the locality from which the fossils he describes from the Quillayute were brought by the Indians, he would have found it to be about two miles from the Devils Club swamp where he says they occur, and the formation lithologically very different from what he describes. It is typical Empire sandstone.

C. E. Weaver, 1912, "A Preliminary Report on the Tertiary Palæontology of Western Washington."[71] Cowlitz formation; the

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[69] *Bull. Geol. Soc. Am.*, XVII., 1906, pp. 451–468.

[70] Geol. Papers, Kans. Acad. Sci., 1908, pp. 131–238.

Table of Correlation of the Formation Names Applied by Various Authors to the Tertiary

	Formation.		Condon, 1880.	Merriam, 1896.	Dall, 1898.	Diller, 1896–1903.	Willis and Smith, 1899.
Pleistocene	Saanich						
	Vashon drift		....	....	....	....	Vashon drift
	Admiralty till		....	....	....	....	Admiralty till
Pliocene	Elk River		....	....	....	Elk River Cape Blanco (in part)	
	Merced		....	....	Coos conglomerate	Coos conglomerate	....
Miocene	Empire		*Solen* beds (in part)	....	*Mytilus* bed Empire Tunnel Point (in part)	Empire Cape Blanco (in part)	....
	Monterey		*Solen* beds (in part)	Carmanah Point (in part)	Astoria sandstone (in part)	....	....
Oligocene	Astoria	Twin River	....	....	....	....	....
		Seattle	Astoria shale	....	Astoria s. s. (in part) Astoria shale *Aturia* bed	....	....
		San Lorenzo	*Solen* beds (in part)	Carmanah Point (in part)	Tunnel Point (in part) Foraminiferal shale......	Oakland limestone?	....
	Sooke		....	Sooke	Sooke		
			White, 1888–9.	Lawson, 1894.			
Eocene	Arago		....	....	Arago	Umpqua — Wilbur, Tyee Arago — Coaledo, Pulaski	....
	Tejon	Olequa	Puget Group	....	Puget Group	....	Lower Puget Burnett Wilkeston
		Chehalis	....	Chehalis sandstone	....	....	Upper Puget Carbonad

ion Names Applied by Various Authors to the Tertiary Horizons of the North Pacific Coast.

Dall, 1898.	Diller, 1896–1903.	Willis and Smith, 1899.	Arnold, 1906.	Reagan, 1908.	Weaver, 1912.
....	....	Vashon drift			
....	....	Admiralty till	....	Quillayute (type section)	
....	Elk River Cape Blanco (in part)				
onglomerate	Coos conglomerate	....	....	Quinaielt (in part)	
lus bed re el Point (in part)	Empire Cape Blanco (in part)	....	Quinaielt	Quinaielt (in part) Quillayute (fauna only) Raft River	Montesano Chehalis (in part)
sandstone (in part)	....	....	Clallam	Hoko	Chehalis (in part) Wahkiakum (in part) Blakely (in part)
.... ia s. s. (in part) ia shale *a* bed	....	....	Mapped with Clallam as undifferentiated Oligocene-Miocene	Clallam	Blakely (in part) Lincoln Creek (in part)
el Point (in part) niniferal shale......	Oakland limestone?	....		....	Wahkiakum (in part) Blakely (in part) Lincoln Creek (in part)
	Umpqua: Wilbur, Tyee Arago: Coaledo, Pulaski	....	Crescent tuffs	Crescent tuffs	
Group	....	Lower Puget Burnett Wilkeston Carbonado	....	....	Tejon
....	....	Upper Puget	....	....	Lincoln Creek (in part) Cowlitz

fauna of the beds on the Cowlitz River below the mouth of Drew Creek is identical with that at Chehalis and Centralia in the lower Tejon (Chehalis formation).

Lincoln Creek formation; this is very vaguely defined. The area shown on the map comprises two different things, Chehalis beds underlying the basalts of the Balch syncline, and a conformable sequence of a late phase of the San Lorenzo formation and an early phase of the Seattle. The fauna listed appears to have come from the basal San Lorenzo beds at Oakville about fifteen miles away. The equivalent beds of Sinclair Inlet are apparently lower San Lorenzo, and those of the Cape Flattery section, like most of the rocks on the west coast of the Olympic Peninsula mapped by Weaver as Lower Miocene, are Cretaceous.

"Tejon formation." The exact use of this formation name in Washington is uncertain. The fauna listed appears to have come from the Olequa beds near Little Falls and on Coal Creek above Stella. If the term Tejon is used in the broad sense that it is by the writers then the reasons for separating the Cowlitz formation which contains a fauna much more closely allied to that at Fort Tejon in California are not apparent. If it is used in a restricted sense for the Olequa beds then it is obviously misapplied.

Blakely formation; this name seems to be intended to cover all the Oligocene-Lower Miocene deposits of the Puget Sound and north coast of Washington. The type-section on Bainbridge Island is the exact equivalent of the Astoria Series as recognized by the writers.

Wahkiakum formation; the Oligocene-Lower Miocene of southwestern Washington. The type-section is Monterey sandstone but many of the fossils listed came from the Astoria beds on Skamokawa and Grays Rivers.

Chehalis formation; the type section is Monterey and Empire, and the fossils listed a mixture of the shale faunas of the two.

Montesano formation; apparently intended as a local name for the Empire sandstone.